National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

WISE Project
Initial Confirmation Review
NASA HQ

August 25, 2004

Meeting Purpose

- Assess the readiness of the WISE project to enter Phase B.
- Update the GPMC on changes to the WISE project since submission of the WISE Phase A Concept Study Report (CSR)

Agenda

9:00	Purpose of the DPMC and Agenda	Wright
9:05	Introduction	Irace
9:15	Science	Wright
9:25	Mission and System Design	Irace
9:45	Project Management	Irace
10:20	JPL Assessment	Simmons
10:25	GSFC Assessment	Scolese
10:30	Summary of TMC Findings	Liceaga
11:00	DPMC Discussion	Figueroa
12:00	Adjourn	

Introduction

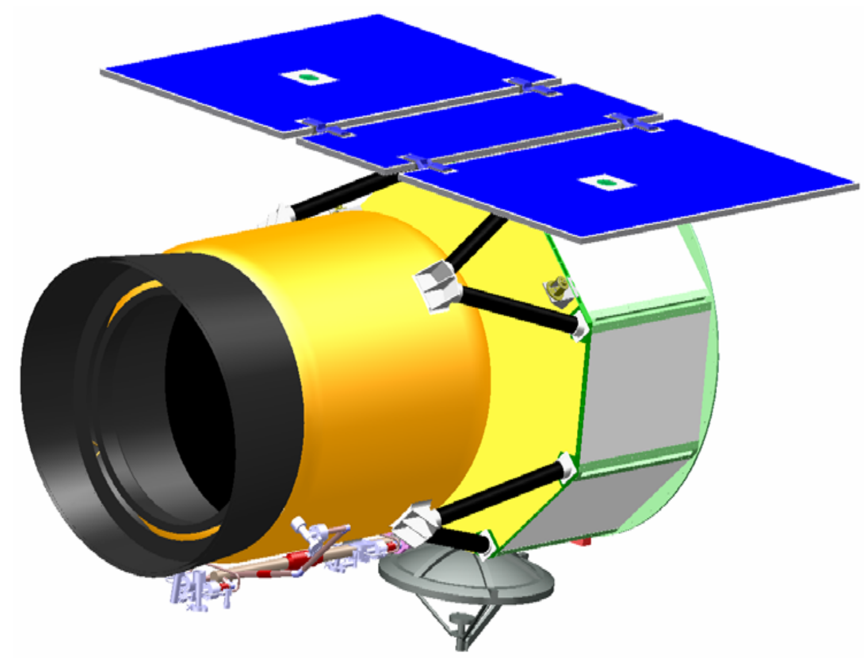
Bill Irace

Project Overview

Science

- *Sensitive all sky survey with 8X (was 5X) redundancy*
  - *Find the most luminous galaxies in the universe*
  - *Find the closest stars to the sun*
  - *Provide the essential catalog for JWST*
  - *Provide lasting research legacy*

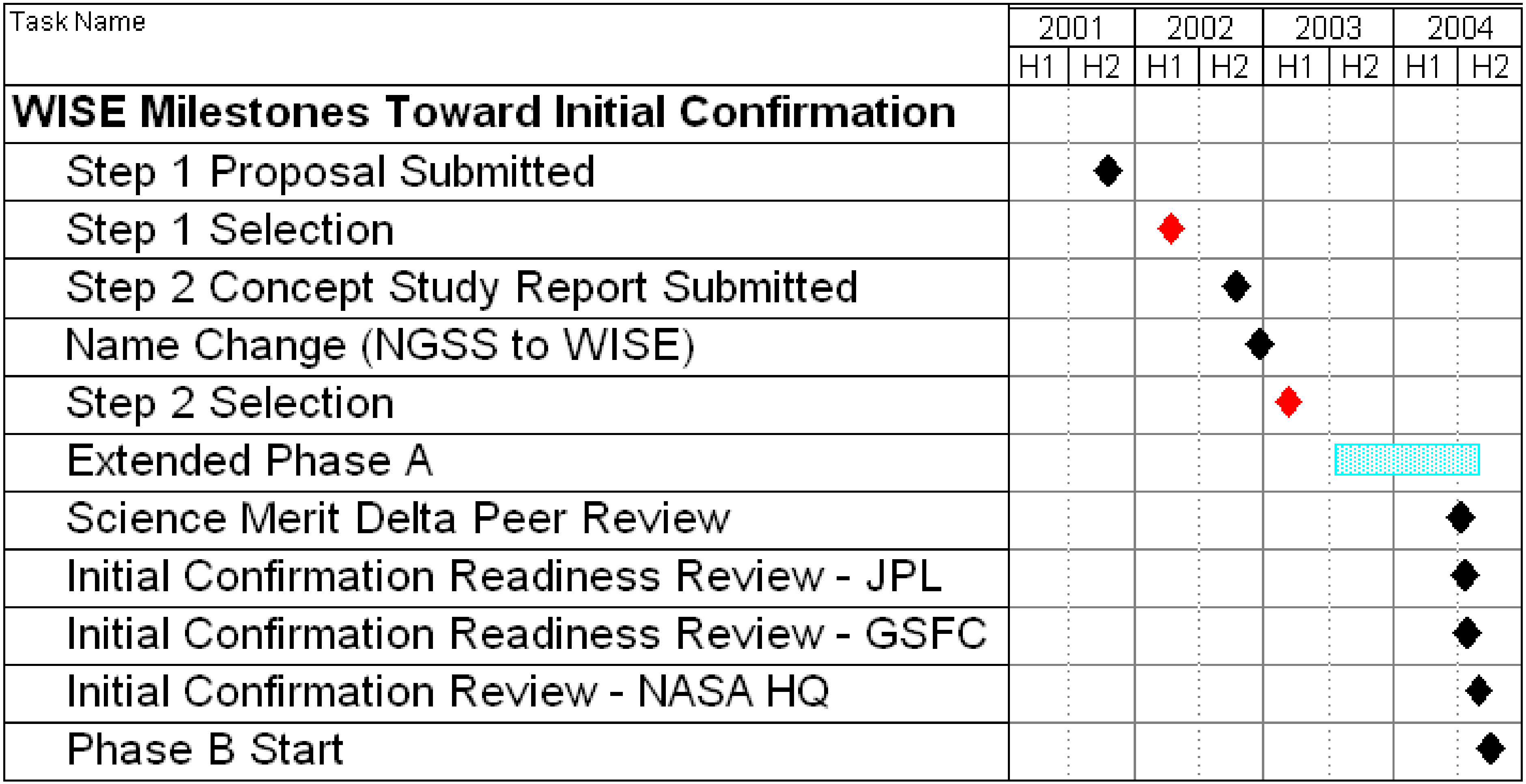
Wide Field Infrared Survey Explorer



Salient Features

- *4 imaging channels covering 3.5 - 23 microns wavelength*
- *40 cm (was 50 cm) telescope operating at <17K*
- *Two stage solid hydrogen cryostat*
- *Taurus launch from WTR in June, 2008*
- *Sun-synchronous 500 km polar orbit*
- *Operational life: 7 months (130% margin)*
- *4 TDRSS tracks per day*

Key Milestones



WISE Selected

- NASA's Space Science AA (Dr. Weiler) selected WISE for a non-competitive extended Phase A study in March, 2003

- Strengths cited at the debriefing following Step 2 selection
  - Strong support for WISE science – JWST precursor
  - WISE science has discovery potential as revolutionary as IRAS
  - WISE mission design is robust
    - Power margin is good
    - Can launch on any day of the year
    - Telescope design is well within state of the art and team capabilities.
  - Team has proven experience and capability

Confirmation Withheld

- Extended Phase A funded to:
  - "..allow further maturation of the WISE concept.."
  - "..make the case for the WISE cost estimate.."
  - "..provide....confidence." [in the cost estimate]

- Confirmation criteria established:
  1) An independent cost estimate validates our proposed cost, **OR** adequate reserves exist to compensate for the difference
  2) WISE science objectives continue to be met

TMC Concerns Resolved

- In addition to cost risk, the following other concerns were raised by the TMC and addressed by the project during the extended Phase A
  - Silicon focal plane development is risky → prototype developed and tested
  - Management team experience→ experienced project manager assigned
  - WISE pointing error budget is incomplete → refined and peer reviewed
  - Performance and lifetime of solid H_2 cryostat → 130% margin retained
  - Optical channel design → refined and peer reviewed

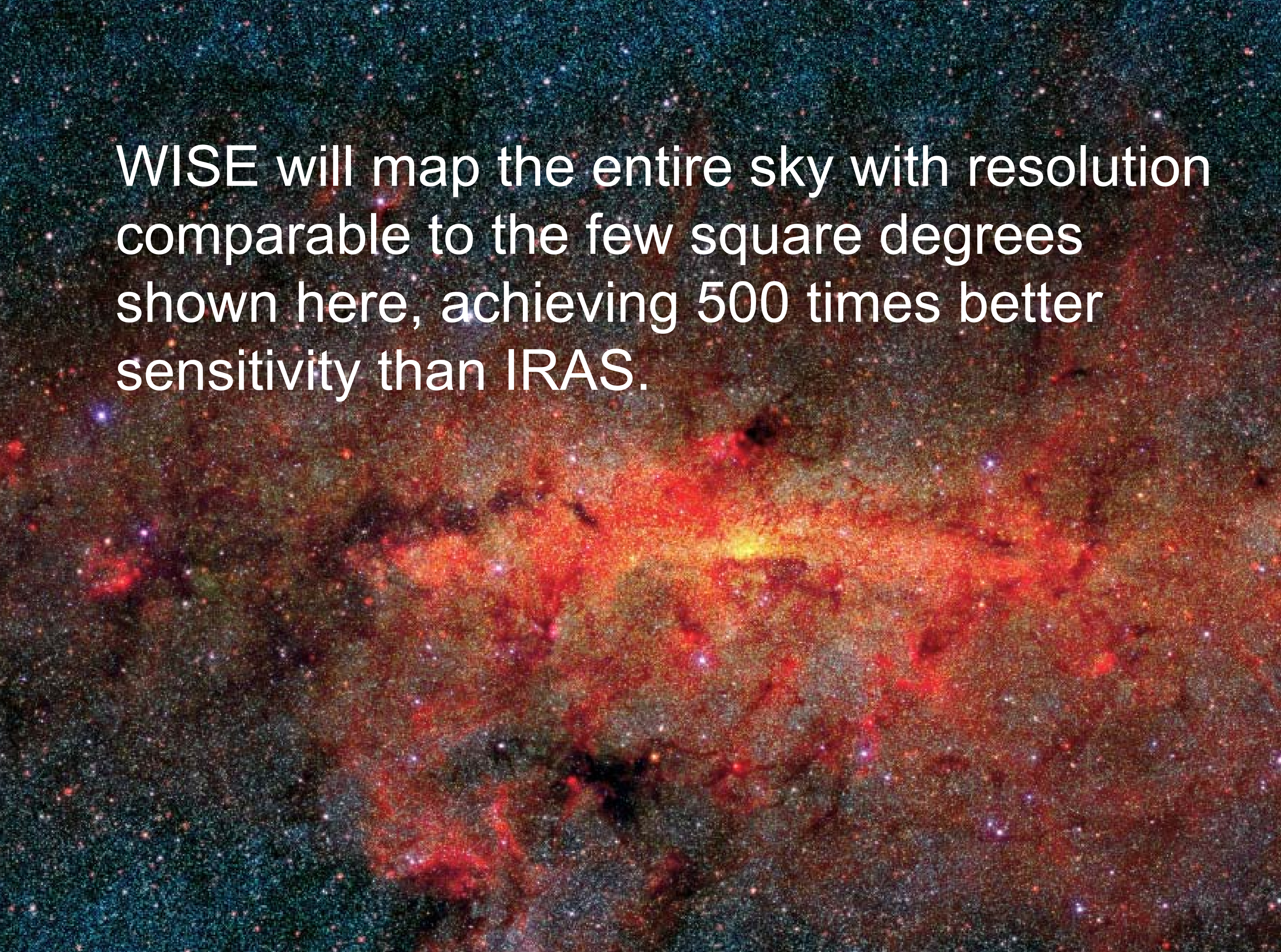
Confirmation Criteria Met

- Extended Phase A activities have reduced implementation risk
  - Design charges (reduced aperture, reduced data volume, telecom simplified
  - Other risk reduction activities
    - Si:As detector fabricated
    - Requirements defined
    - Cost estimates and schedules scrubbed
    - Reserve increased from 20% to 26%
- **Independent and WISE team cost estimates have converged**
  - JPL SMO + 3% (was + 10%)
  - TMC + 10% (was + 17%)
- **Baseline science objectives continue to be met**
  - Science impact of descopes minimal
  - Peer review panel supports science

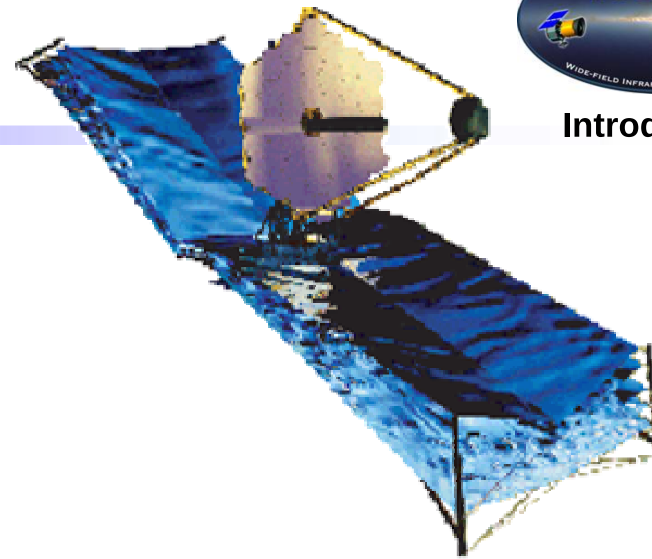
Science

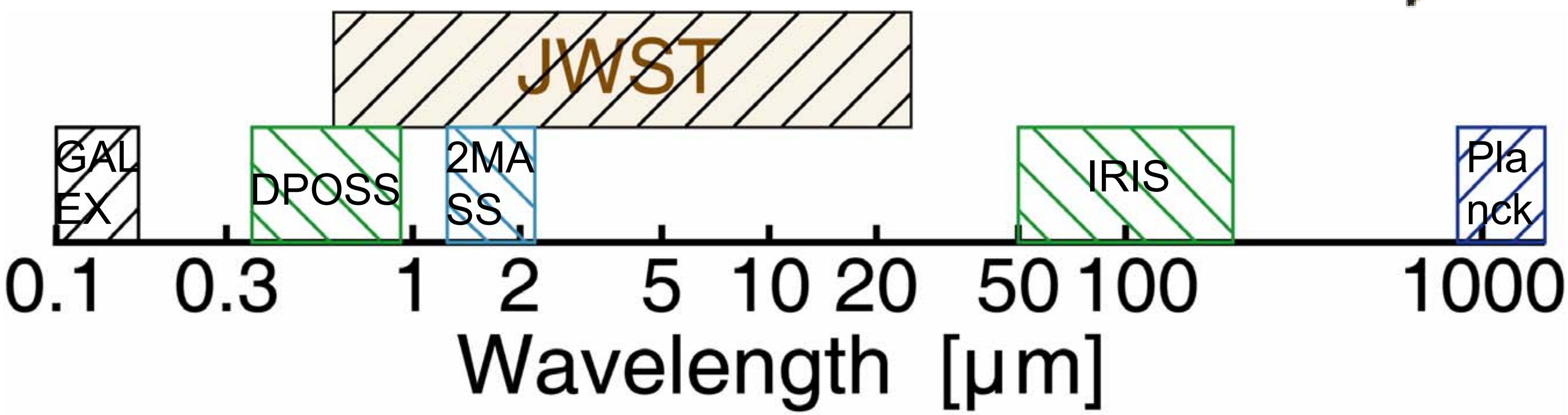
Ned Wright, UCLA

Twenty years ago IRAS gave us what is still our best view of the mid–infrared sky.


WISE will map the entire sky with resolution comparable to the few square degrees shown here, achieving 500 times better sensitivity than IRAS.

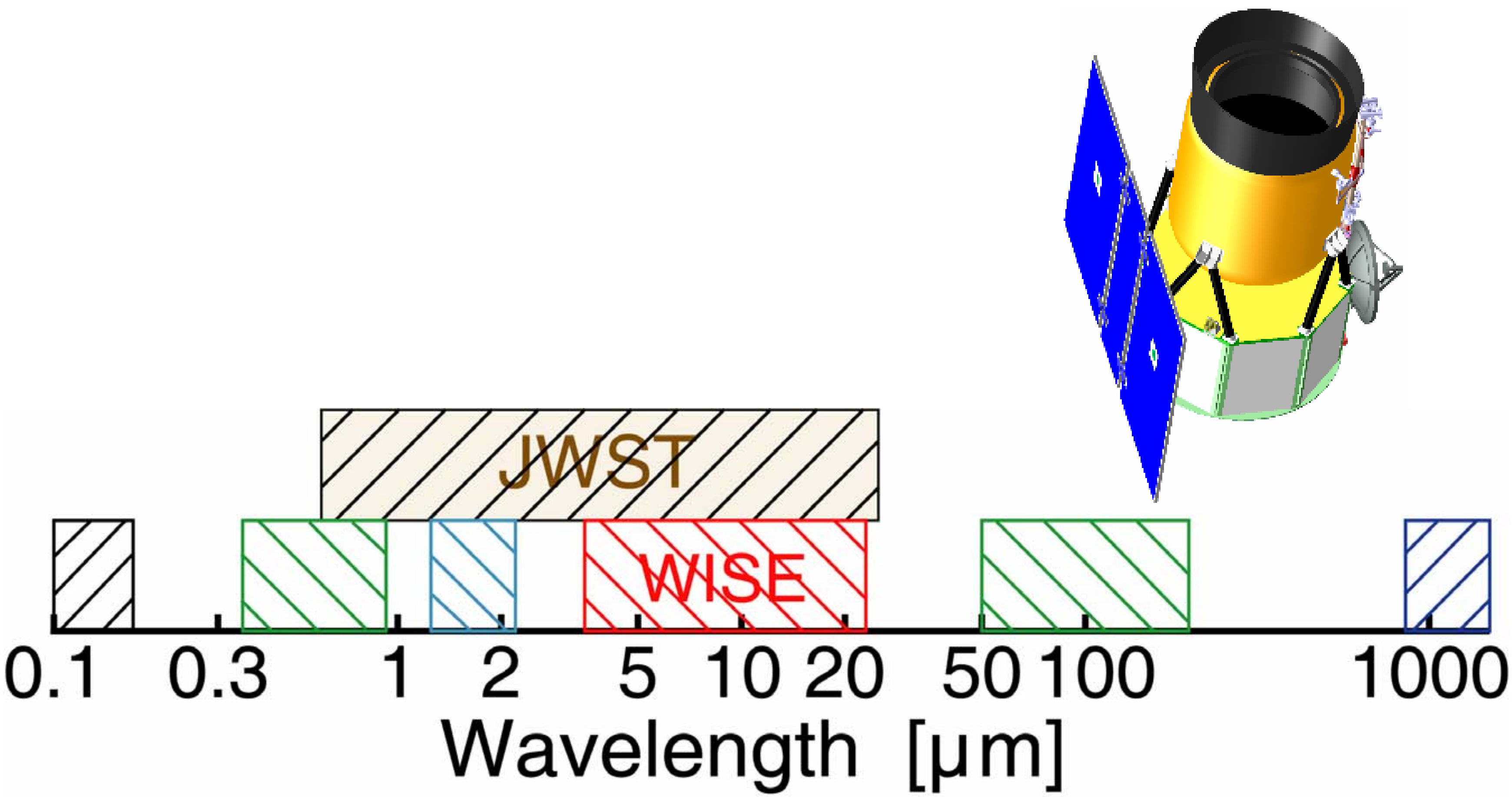
James Webb Space Telescope





- JWST science will be supported by existing and planned large scale, sensitive surveys except in a “gap” between 2.2 and 50 μm

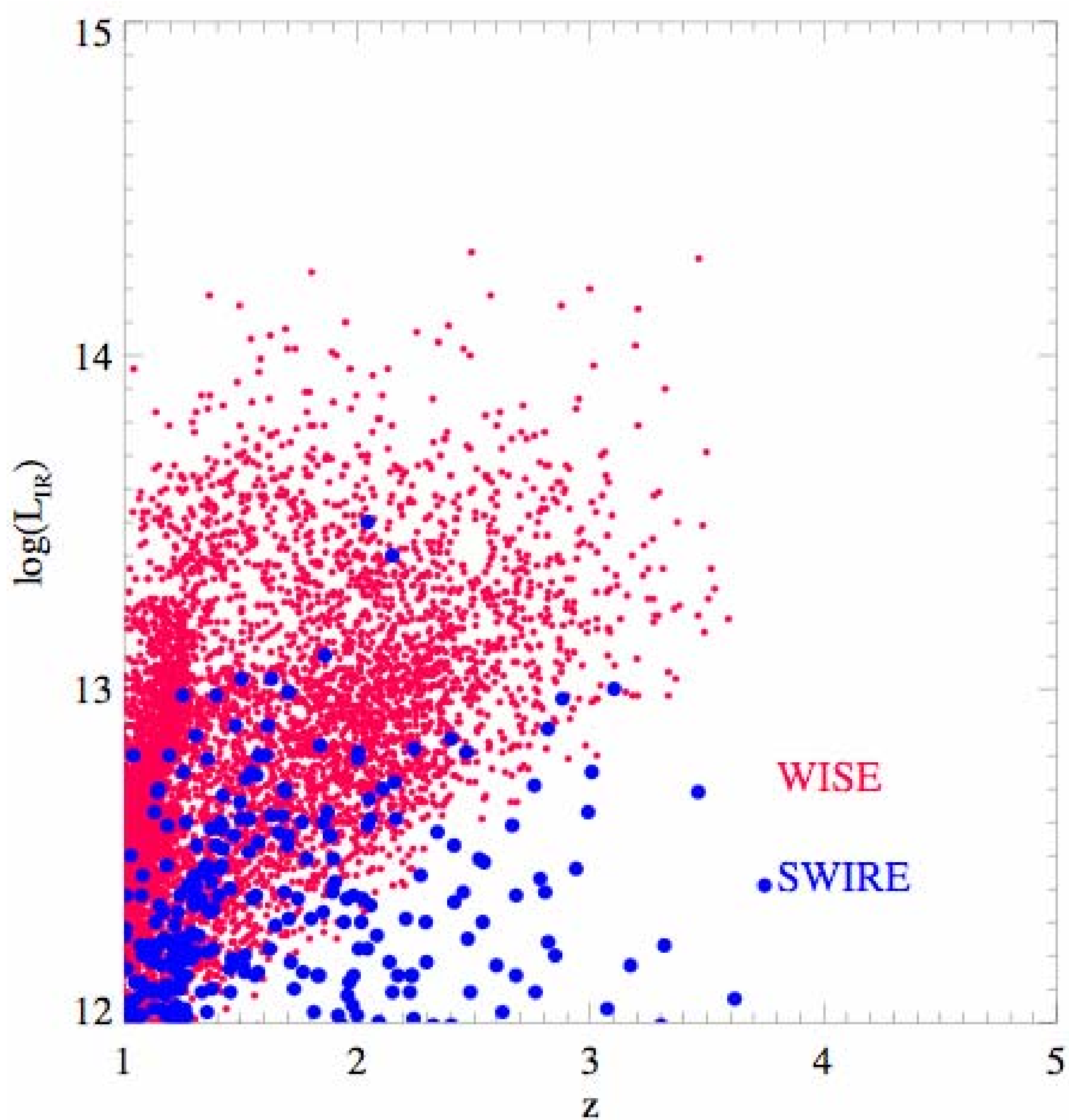
WISE Will Fill "the Gap"



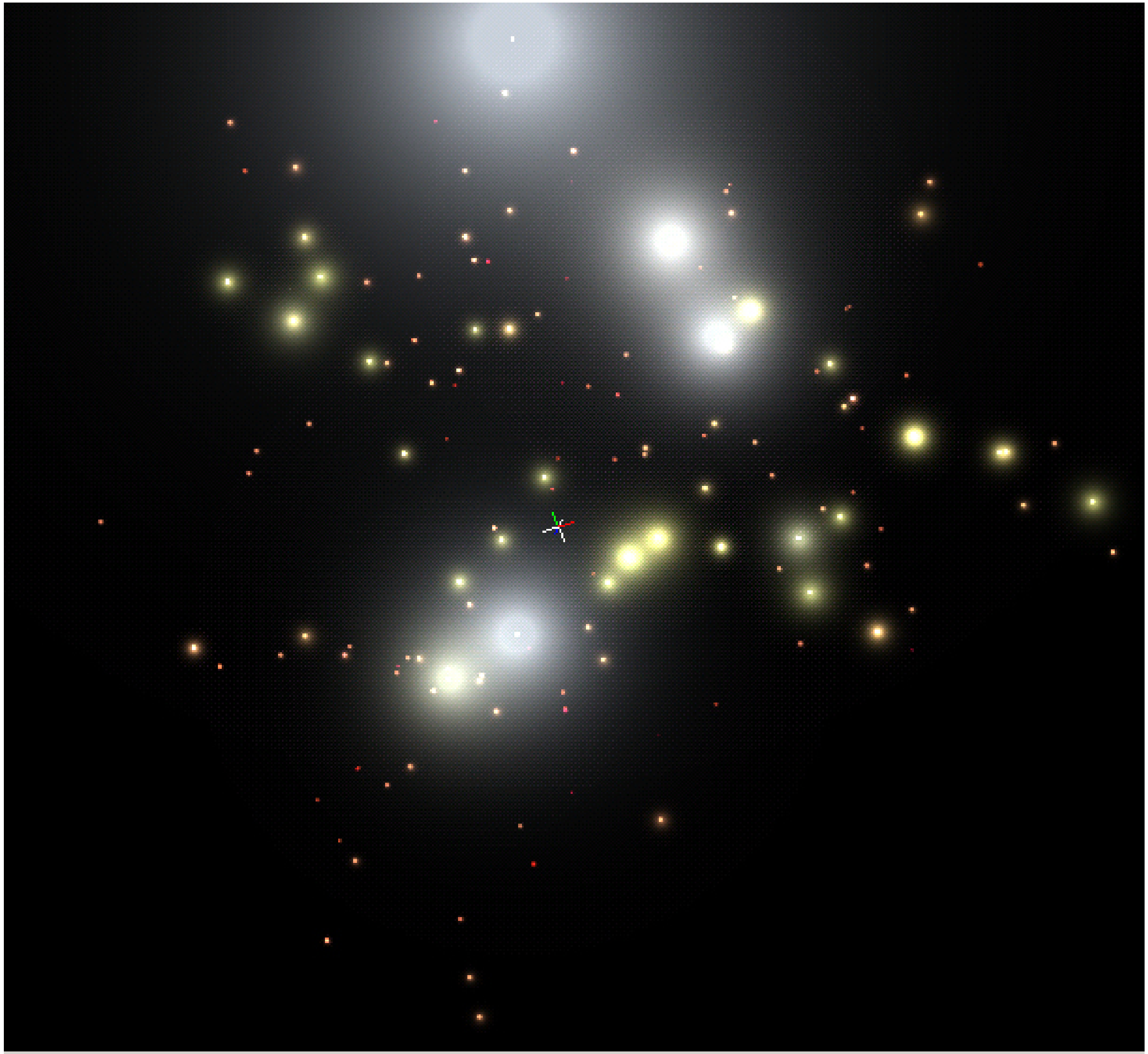
- The WISE mission will fill this gap in the support for JWST science

WISE will find the most luminous galaxies in the universe

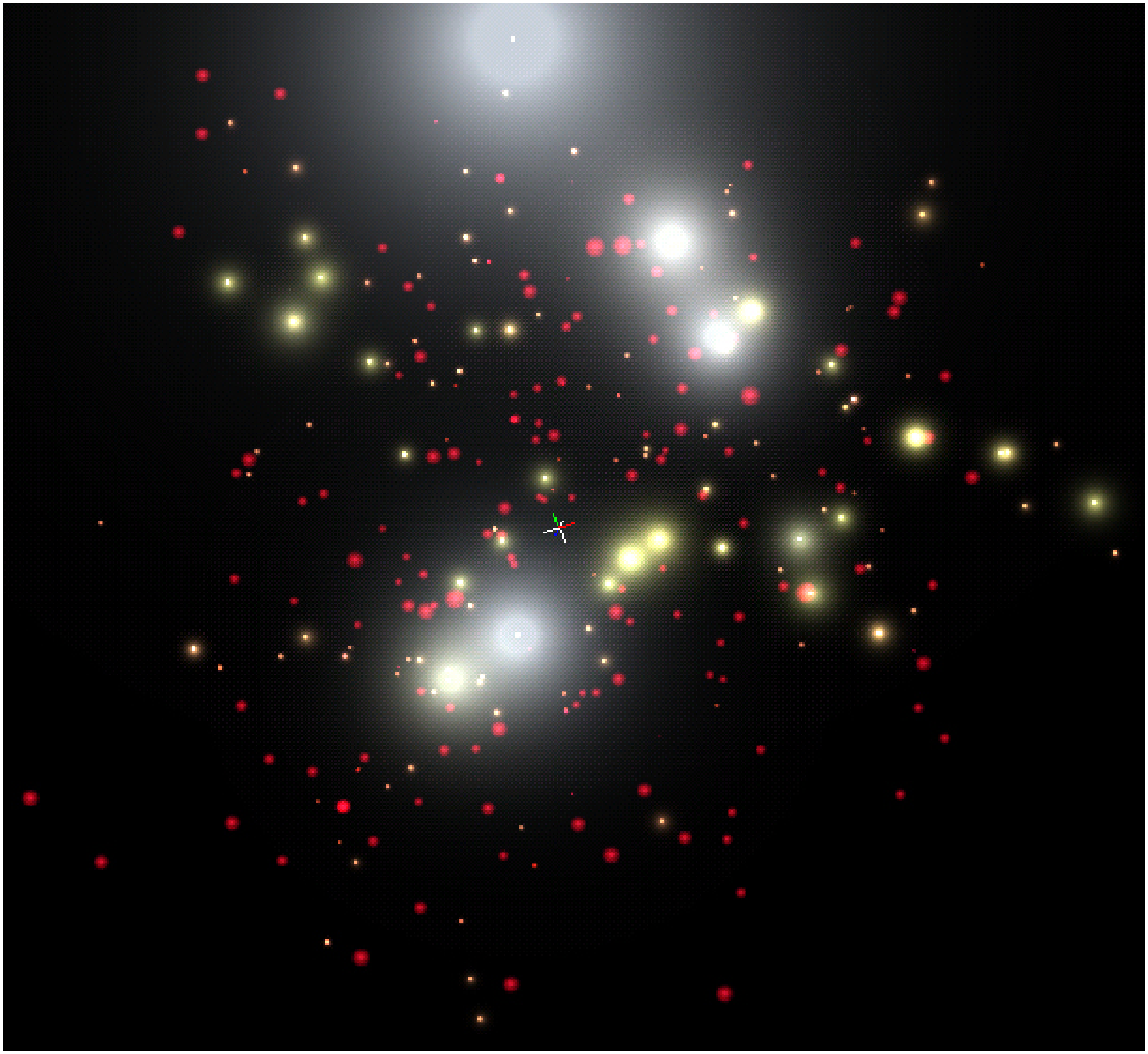
- Comparative WISE & Spitzer (SWIRE Legacy) volume sensitivity to ULIRGs
- Based on latest models by Kevin Xu and observed Spitzer 24µm counts
- Predicts WISE will see ~10^7 LIRGs at 23 µm across the sky, of which 6% will be HyLIRGs with z > 2



Known Stars within 25 lightyears



WISE stars within 25 lightyears



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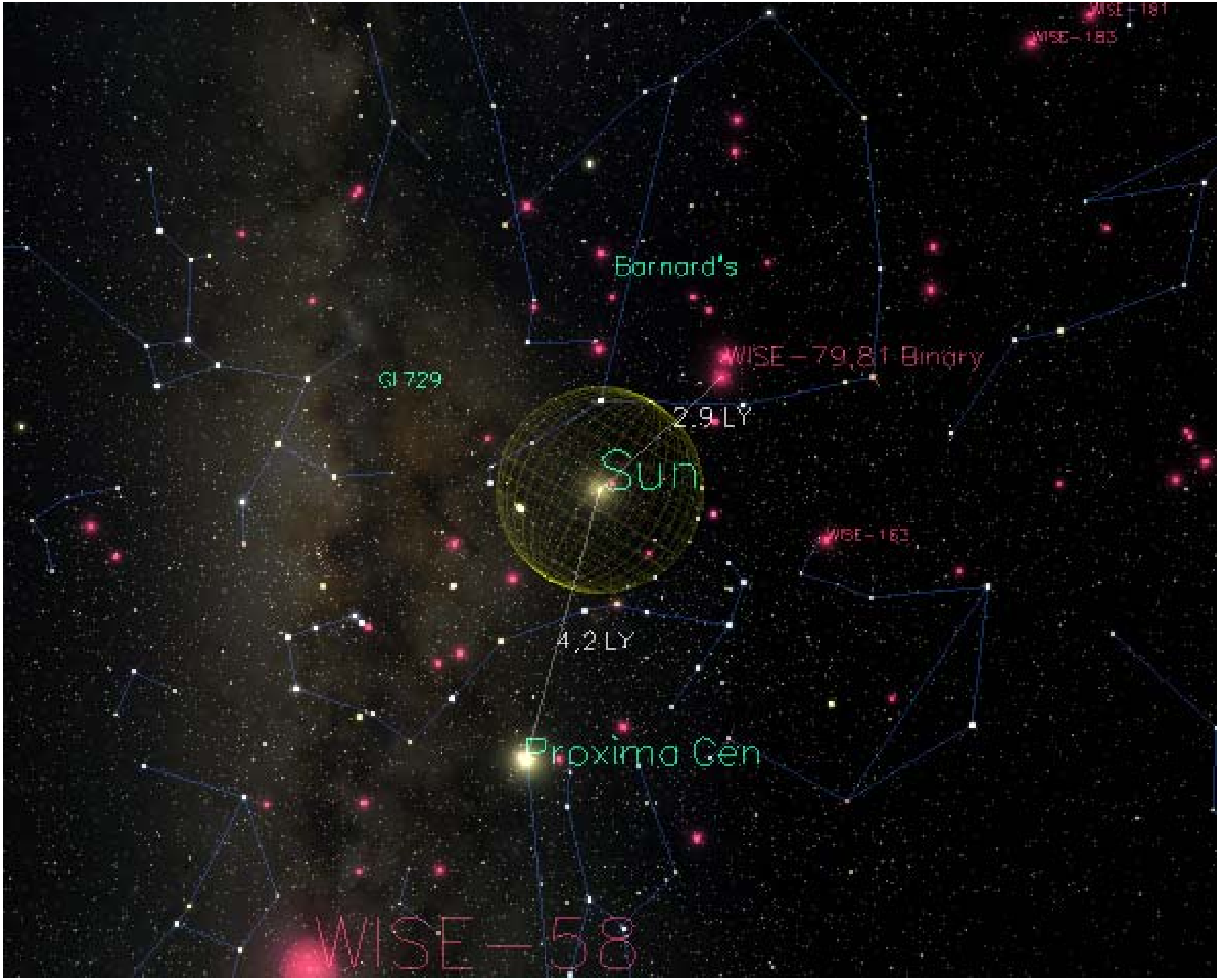
The closest stars…



Requirement	Baseline Mission (L1 Reqmts)	Minimum Mission
Mission Cost	• < \$180 M FY02	• < \$180 M FY02
Sensitive All Sky Survey in mid-infrared (2.2 – 50 μm)	• Detect nearest stars to the Sun • Most luminous galaxies in the Universe. • Four filter bandpasses • Cover at least 95% of the sky	• Sensitivities comparable to 2MASS at 2.2μm and to IRIS at 50μm. • Three filter bandpasses • Cover at least 90% of the sky
Mission Survey Duration	• At least 6 months following checkout	• At least 6 months following checkout
Image Atlas	• Combine multiple exposures at each position on the sky.	• Combine multiple exposures at each position on the sky.
Source Catalog	• Reliability>99.9% for sources SNR>20 • At least 95% complete for sources SNR>20 • 7% relative photometric accuracy • Catalog positions error <0.5” with respect to 2MASS catalog positions for sources SNR>20 • Include sources to SNR 5σ in any band • Completeness and reliability characterized at all flux levels	• Reliability>99.9% for sources SNR>20 • At least 90% complete for sources SNR>20 • 10% relative photometric accuracy • Catalog position error <1” with respect to 2MASS catalog positions for sources SNR>20.

- WISE Delta Science Peer Review held 8 July 2004 to evaluate merit of revised WISE concept against original science objectives

- Final report of the ∆Science Peer Review panel finds:
  - WISE continues to meet original science objectives, and remains a compelling mission, if held to Level 1 science requirements
    - "The huge sensitivity gains relative to COBE and IRAS, and the sky coverage gains relative to Spitzer, are clearly worth the cost and effort."
  - Minimum mission should not deviate very much from Level 1 [sensitivity] requirements to address original science
    - "The minimum mission identified by the team…is not a viable option to meet the original science goals, even though it could provide a valuable database in its own right."

- WISE minimum mission characteristics will be reevaluated in Phase B

Conclusion

- WISE results will excite both scientists and the general public:
  - Measure >100,000 asteroids in the Solar System
  - Find the 2/3 of the stars in the solar neighborhood that have not yet been seen, including *the closest stars to the Sun*
  - Study star forming regions in the Milky Way and in *the most luminous galaxies in the Universe*
  - Provide an independent test of the *dark energy content of the Universe* by correlating the large scale structure seen by WISE with the CMB seen by WMAP
- WISE will provide a legacy that endures for decades, enabling studies of objects that have yet to be discovered

Mission and System Design

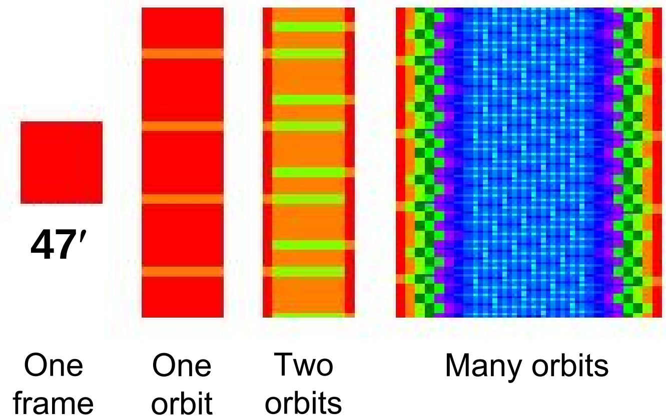
Bill Irace

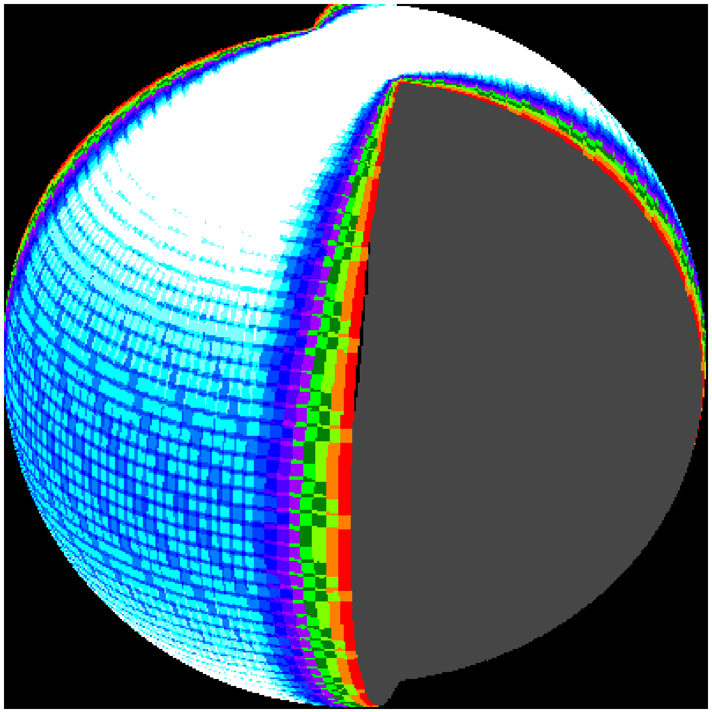
Key Mission Events

Mission Phase	Time	Events/Notes
Launch (L)	21 June 2008 (Baseline w/ daily launch windows)	Launch Taurus 2210 500km sun-synch orbit, spacecraft separation, autonomous Sun Acquisition, 3-axis stabilization, deployment of solar arrays
Observatory Initialization	L + 180 min	Subsystems checkout, calibration, additional ground contacts
Cover Ejection	L + 2 wks	Cover eject, health diagnostics, tests
End of In-Orbit-Checkout	L + 4 wks	Start of continuous data collection; 11-s exposure
Science Data Downlinks	Every ~6 h	~4 Downlinks/day
End of Survey	L + 7 mos	Possible extended missions to L + 13 mos
Preliminary Catalog Release	L + 13 mos	First 50% of sky
Final Catalog Release	L + 24 mos	All sky

Simple Mission Design

- Single observing mode
- Scan mirror “freezes” orbital motion enables efficient surveying
  - 8.8-s exposure/11-s duty cycle
  - 10% frame to frame overlap
  - 90% orbit to orbit overlap
- Sky covered in 6 months of observing
- Minimum of 8 exposures/position after losses to Moon and SAA

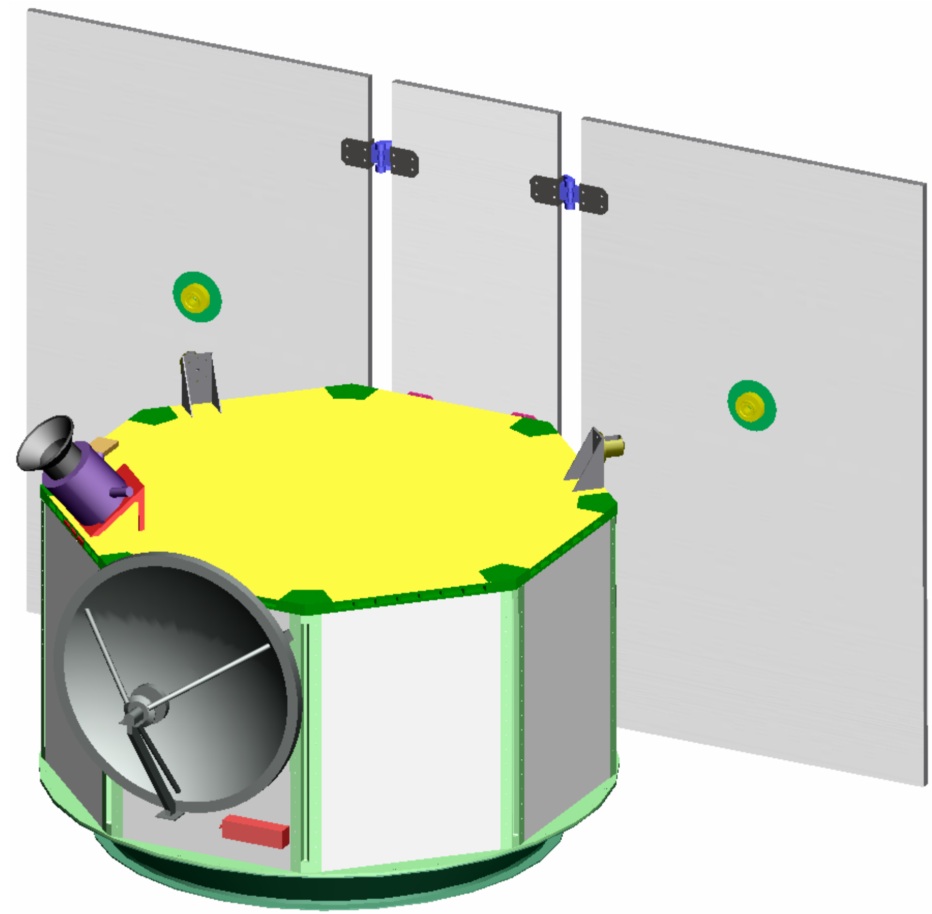




WISE Spacecraft

- "RS-300" architecture (BATC)
  - 3-axis stabilized
  - Single string
  - Integrated single-box avionics
    - DI, OE, Kepler heritage
    - RAD750 processor
  - Single deployment solar arrays
  - Basic flight software
  - Software test bed

- Modifications for
  - Primary structure (aluminum)
  - Earth-avoidance software
  - Telecom
    - 85.9 GB RAID data storage
    - 20W TDRSS Ku band science data link
    - 0.8 m diameter fixed high gain antenna
    - 120 Mbps data rate

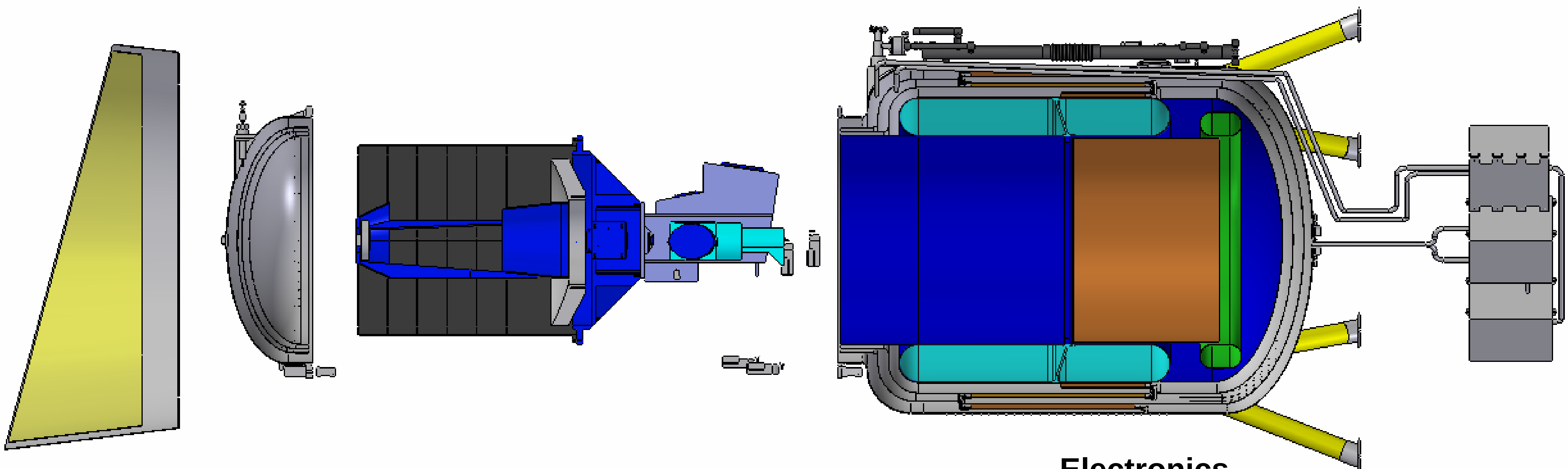


WISE Payload

2-Stage Aperture Shade
- Radiatively cooled
- Protects aperture from stray sun/ earth radiation
- Inner shade <110 K

Telescope Assembly
- 40-cm afocal front end
- Scan mirror
- Refractive MWIR imager
- Reflective LWIR imager

Cryostat
- 2-stage solid hydrogen
- Secondary tank cools optics & MCT FPAs
- Primary tank cools Si:As FPAs
- 2 vapor-cooled shields
- Composite support-tube structure

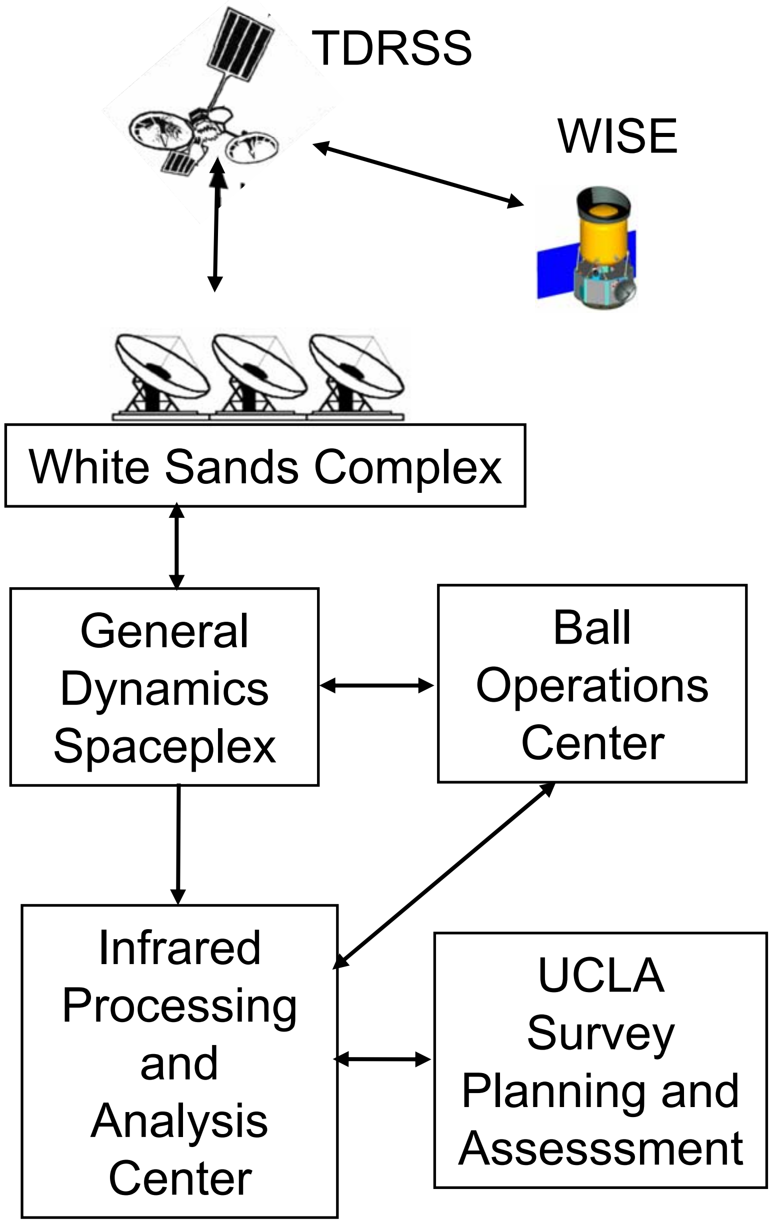


Cooled Aperture Cover
- Deployed on-orbit
- Seals vacuum space on ground

Focal Planes
- 2 MWIR MCT arrays
- 2 LWIR Si:As arrays
- Cryogenic cables

Electronics
- Focal-plane electronics
- Command/Control/ Telemetry
- Housekeeping/scan-mirror control
- Data compression/Binning

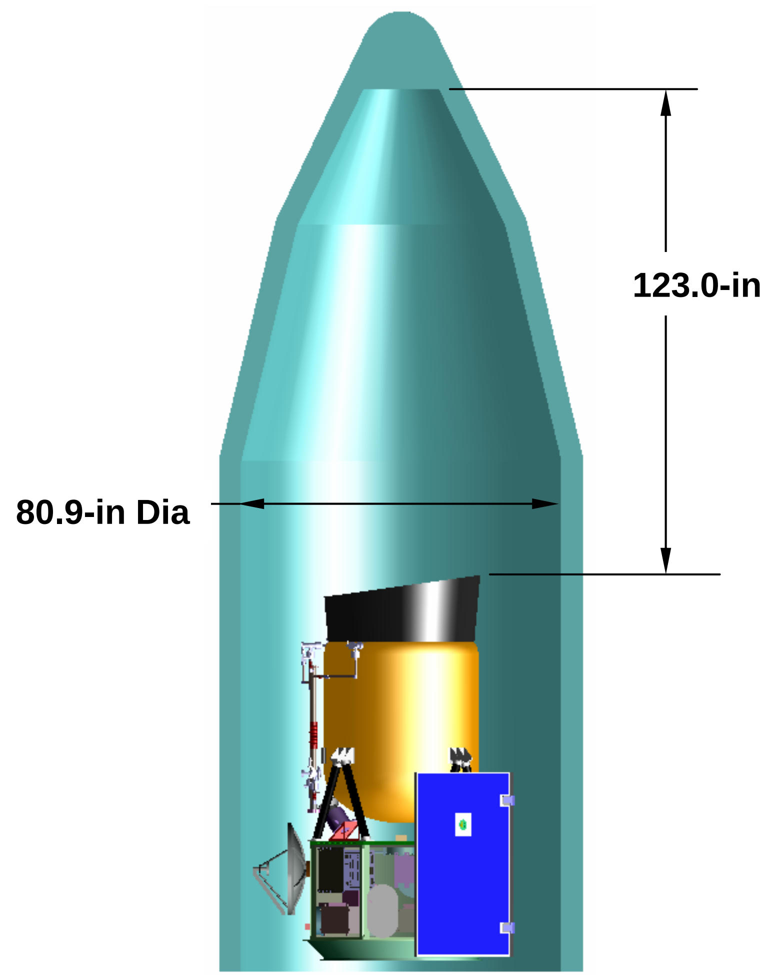
Mission Operations Approach



- TDRSS tracking
  - 4 tracks per day
- Mission Operations Center at BATC
  - Engineering analysis
  - Uplink preparation
- Raw science data transferred from GD/Spaceplex to IPAC
- PI leads survey planning/assessment team
- Automated science data processing at IPAC
  - Modeled closely on successful 2MASS pipeline

Taurus Launch System Meets WISE Needs

- Orbital Sciences 3-stage 2210 launch system
  - Standard 92-inch fairing
- Deliver 670 kg to 500 km circular polar orbit
  - WISE mass margin 45%
- Injection errors make spacecraft propulsion unnecessary
  - Injection Apse ±10 km
  - Non-injection Apse ±50 km
  - Mean altitude ±30 km
  - Inclination ±0.15°
- Six successful launches (of seven)
- Availability TBD



Design Changes
Reduce Risk and Cost

- Reduced aperture (50 → 40 cm)
- Increased pixel IFOV (2.00 → 2.75 arcsec)
  - Offsets sensitivity loss from reduced aperture
  - Increases survey reliability (repeats increased from 5x to 8x)
  - Reduced data volume
- Reduced data volume
  - Digitally binned 23 μm band data (2x2 → 1)
  - Added square root encoded data compression (1.36:1)
  - Reduced Ku band transmitter power (50W TWTA → 20W SSA)
  - Reduced TDRSS downlink data rate (320 Mbps → 120 Mbps)
- Reduced preliminary catalog release to first 50% of sky
- Eliminated high gain antenna gimbal

Design Margins Remain Robust

Parameter	Current WISE Margin (Relative to L1 Rqmt)	Previous WISE Margin (Relative to L1 Rqmt)
Mass	45%	26%
Power	45%	39%
CPU Utilization	105%	130%
CPU Memory	80%	80%
Communication Link	3 dB	4 dB
On-board Data Storage	259%	72%
Cryostat Lifetime	132%	132%
Sensitivity	74% at 3.5 μm 40% at 23 μm	118% at 3.5 μm 113% at 23 μm
Image Quality	25% at 3.5 μm	25% at 3.5 μm

Management

Bill Irace

Project Team Roles

- Ned Wright - UCLA
  - Principal Investigator
  - Science Team Lead
  - Survey Design and Execution
- Jet Propulsion Laboratory
  - Project Management
  - System Engineering
  - Mission Operations Leadership
  - Mission Assurance
- Utah State University – SDL
  - Science Payload
    - DRS/Rockwell – Focal Planes
    - SSG – Optics
    - LMATC—H_2 Cryostat
- Ball Aerospace
  - Spacecraft
  - Flight System ATLO
  - Mission Operations
    - General Dynamics – Spaceplex
- Caltech - IPAC
  - Science Data Processing
- UC Berkeley - SSL
  - Education and Public Outreach

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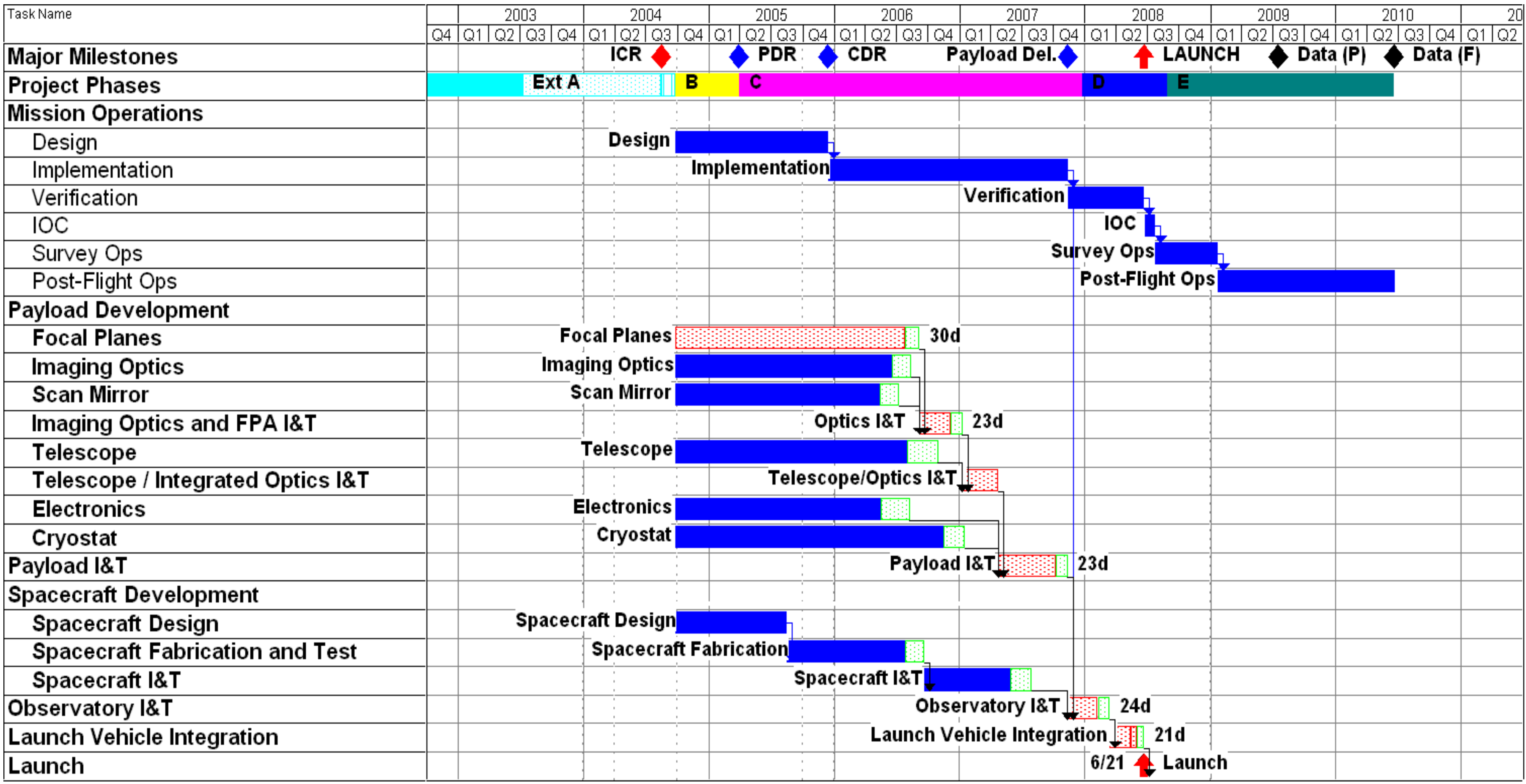
Robust Schedule Includes Funded Reserve



- Critical path (red) through the focal planes
- Funded schedule reserve (green) distributed throughout (meets JPL FPP standards)

Rigorous Budget Development Process

- Developed detailed costing guidelines
  - Incorporate descopes
  - Incorporate refined level 2 schedule with dates adjusted for extended Phase A
  - Price in RY $ with approved forward pricing rates
  - WBS designed for accurate/timely cost tracking
  - Spares requirements defined
  - Fee assumptions defined
  - Draft requirements down to Level 3
  - RFP's with Phase B SOW to BATC and SDL
- Prepared new baseline estimate for Phases B,C/D,E
  - Managers re-estimated all JPL accounts (bottom up with analogy checks)
  - BATC and SDL prepared firm proposals for Phase B and revised estimates for Phases C/D/E (bottom up with analogy checks)
  - IPAC re-estimated all Phases (bottom up with analogy checks)
  - UCLA inflated CSR plan to revised schedule (no change in scope)
- Determined real year cost cap which is compliant with the AO's FY 02 cost cap
- Reserve = RY $ cost cap – new baseline estimate
- Published Baseline Budget Plan document

WBS/Budget (RY$)

- **WISE Project** — **$208.7M**
  - Reserve — **$30.7M**
  - ONC — **$2.3M**
  - 1.0 Project Mgmt — **$5.4M**
  - 2.0 Proj Sys Eng — **$3.1M**
  - 3.0 Mission Assurance — **$3.2M**
    - 3.1 - 3.8 JPL MAM — **$3.0M**
    - 3.9 S/W IV&V — **$0.2M**
  - 4.0 Science — **$7.7M**
    - 4.1 Project Scientist — **$2.9M**
      - 4.1.1 JPL Office
      - 4.1.2 IPAC Scientists
    - 4.2 Principal Investigator — **$4.8M**
      - 4.2.1 PI Office
      - 4.2.2 EPO
  - 5.0 Payload — **$49.3M**
    - 5.1 Contract Mgmt — **$1.3M**
    - 5.2 Payload Development — **$47.8M**
    - 5.3 Obs Operations Support — **$0.1M**
  - 6.0 Observatory — **$36.1M**
    - 6.1 Contract Mgmt — **$1.2M**
    - 6.2 S/C Development — **$31.7M**
    - 6.3 Obs ATLO — **$3.2M**
  - 7.0 Mission Operations — **$22.6M**
    - 7.1 MOS Mgmt — **$0.7M**
    - 7.2 MOS Sys Eng — **$1.0M**
    - 7.3 Eng Operations — **$6.3M**
    - 7.4 Science Operations — **$14.6M**
  - 8.0 Launch Services — **$48.3M**

Legend

- JPL Tasks
- JPL-funded Tasks
- Bypass-funded Tasks

Note

All costs are RY $M, cost to NASA

Budget Comparison
$M FY02

Item	CSR	Ex Phase A
PM/SE/MA	14	13
Science and EPO	5	5
Payload	44	43
Observatory	33	32
Mission Ops - BCDE	19	18
Launch Vehicle	44	43
Subtotal	159	154
Reserves	21	26
Reserve %	20	26
Total NASA Cost	180	180
Contributions	1	1
Total Mission Cost	181	181

Estimate Comparison - $M FY02

	WISE Project	TMC	JPL - SMO	JPL - Costing Office
PM/SE/MA	13	14 - 16	12 - 14	
Science and EPO	5	3	5 - 7	
Payload	43	36 - 57	38 - 48	
Spacecraft/ATLO	32	38 - 47	36 - 42	
Mission Ops - BCDE	18	16 - 19	12 - 13	
Launch Vehicle	43	43	43	
Subtotal	154	162 -173	146 - 167	
Reserves	26	32 - 33	26 - 32	
Reserve %	26	29	26	20
Subtotal	180	194 - 206	173 - 199	~180
Contributions	1	1	1	
Total Mission Cost	181	191 - 207	174 - 200	~181

Response To TMC Assessment
Cost Risk

TMC Assessment

- Cost risk is “low end of medium” - TMC estimates remain higher than project estimates
  - Spacecraft design heritage
  - Cryogenic payload complexity

Project Response

- Fidelity of project estimate has improved during extended Phase A
  - Requirements developed to level 3 – backed by telecom and pointing studies
  - Payload - Spacecraft interface roles and requirements developed
  - Level 2 schedule detailed and scrubbed
  - Compliance with JPL design practices reviewed
  - Bottom up estimates are backed by updated vendor quotes
  - Phase B costs backed by negotiated contracts
  - Phase C/D/E costs backed by top management
- Spacecraft bus estimates are backed by Cloudsat, DI, OE, and Kepler experience
- Payload has very close technology heritage to WIRE – complexity is well within experience range of implementing organizations
- Cost risk is effectively mitigated
  - Experienced management team (IRAS, WIRE, COBE, WMAP, Spitzer)
  - Robust schedule
    - 121 days of funded reserve on critical path
    - 90 days of funded reserve plus 65 days of slack on spacecraft path
  - 26 % budget reserve

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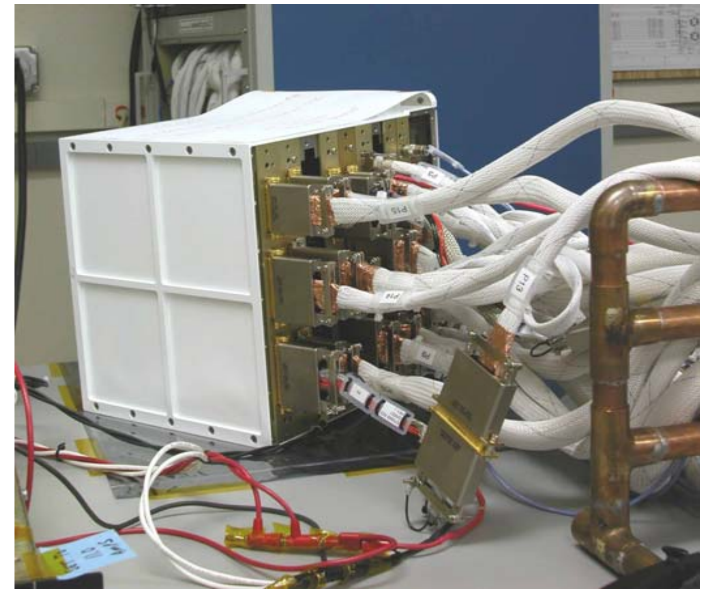
Spacecraft Cost/Heritage

- BATC has derived the RS-300 conceptual design from the successful BCP2000 line of spacecraft
  - As-built costs from multiple builds of the BCP2000 provides a good range of costs for WISE by analogy
  - Cloudsat adaptations of BCP 2000 baseline are similar to the WISE adaptations of the RS 300 baseline
  - Cloudsat EAC is 3% higher than original estimate
- RS300 platform design is mature
  - CDR completed 12/03
  - First build of the RS-300 spacecraft for the OE mission is starting ATLO
  - Kepler using redundant version of RS300 single box central avionics
- WISE development cost risk is low
  - RS300 is generally more capable than WISE requirements
  - Potential benefit of joint buys with Kepler not included in cost estimate
  - Most development costs are based on OE as-built experience
    - OE EAC is 3% higher than original estimate
  - All WISE-unique elements have been estimated as new development based on proven architecture
    - Telecom subsystem, mechanical structure and thermal, mission unique board (developed for every mission), earth avoidance fault protection

OE is in ATLO

OE bus ready for subsystem integration



Avionics box
(Identical to WISE)

Cryogenic Payload Complexity

- WISE cryogenic payload is of similar complexity to WIRE
  - Both developed by SDL, DRS, and LMATC
  - Both use large detector arrays
  - Both use the same cryostat conceptual design
    - ~60% direct heritage to WIRE in drawings
  - Both use a moderately large optical aperture
    - 40 cm WISE; 30 cm WIRE
    - SSG routinely producing cryogenic optical systems of this size and complexity
- WISE implementation team has extensive cryogenic system experience
  - PI participates in Spitzer and WMAP
  - JPL provided project management and system engineering for multiple cryogenic payload missions
    - IRAS, WIRE, Spitzer; TES
  - SDL developed WIRE and SPIRIT-III
  - LMATC/SDL team selected for JWST MIRI cryostat development
- WISE payload cost based on WIRE/SPIRIT-III as-built costs
- The payload concept, internal interfaces, and requirements have been developed during extended Phase A
- Key detector technology (Si:As) advanced during extended Phase A
  - Detector material, readout fabricated

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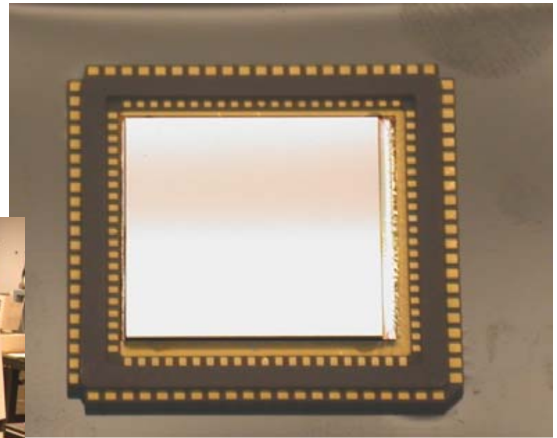
Detector Development Risk is Retired

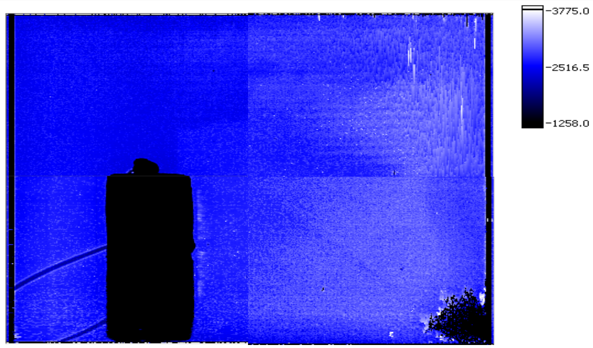
- WISE hybrid performance
  - Dark current better than spec.
  - QE meets spec.
  - Operability and uniformity are acceptable
  - Power meets spec.
  - Read noise exceeds spec
    - Sensitivity loss 5%

- Detector and readout material which is in hand is acceptable for flight if necessary.

- A decision on a second readout run will be made early in Phase B after further testing.



Si:As Hybrid



10 μm Response Image

Satellite Chip with bond wires obscure pixels in one quadrant

Confirmation Gate Products Status (per Code S Management HB)

Task	Status
Program Scientist Led	Complete
1. Establish PI vs. Facility class miss.	Complete
2. Issue AO	Complete
3. Establish science team policies	Complete
4. Establish science data center	Complete
5. Establish Data rights/access policy guidelines	In work
Program Executive Led	
6. Determine governing PMC	TBD
7. Establish budget cap	Complete
8. Phase B performance metrics	TBD
9. Plan for independent assessments	TBD
10. Program requirement	N/A
11. Draft Level 1 requirements	Complete
12. Verifiable technology at >TRL 5	Complete
13. Phase B Confirmation Assessment	Complete – TMC assessment
14. JPL Phase B task plan	Complete
15. Environmental assessment studies	Complete
16. Non NASA LOA's	N/A
17. Non NASA MOU's MOA's	N/A

Confirmation Gate Products Status (cont.)
(per Code S Management HB)

Task	Status
Implementing Center Led	
18. Life cycle cost estimates	Complete
19. Complete Phase A trades	Complete
20. Ops concept and tracking provider assessment	Complete
21. Develop Program (Project Plan)	Complete
22. Finalize launch vehicle performance requirements	Complete
23. Telemetry, command and tracking strategy	Complete
24. Environmental Assessment / Impact study	N/A
25. Identify risks / mitigations	Complete
26. Develop acquisition strategy	Complete
27. Prepare Phase B contracts	Complete
28. Establish document tree	Complete
29. Draft EPO plan with 1-2% funding	Complete

Open Issues

- Launch vehicle assignment
  - Redirection to Delta 7320
  - Co-manifest
  - Environment definition is required early in Phase B

- Potential change to Minimum Mission
  - WISE minimum mission characteristics will be reevaluated in Phase B

Conclusions

- Technical Risks Decreased
  - Descopes implemented (Primary Mirror (50→40cm), Ku-band transmitter simplified, HGA actuators eliminated)
  - Design margins improved (mass, sky repeats, data storage)
  - LWIR detector developed
- Implementation Risks Decreased
  - Higher fidelity plan resulting from Extended Phase A activities
  - Budget backed by Phase B proposals and high fidelity C/D/E estimates
  - Reserve increased from 21% to 26%
  - Substantial funded schedule reserve (121days on critical path)
  - Experienced team
- Baseline science objectives continue to be met

WISE is ready to start Phase B

JPL Assessment

Larry Simmons

Director for Astronomy and Physics

Spacecraft Development Oversight

- JPL GPMC reviewed readiness of WISE to proceed to Phase B on July 19, 2004
- Recommendations were made by Project and several independent review groups provided assessments
  - NASA Technical, Management and Cost Reassessment (Carlos Liceaga) showed significant improvements in risk posture since concept study review, resulting in low end medium risk rating
  - JPL Systems Management Office rates project green in all categories (programmatic, technical, schedule and cost)
  - JPL Costing Office rates project green with a low to moderate risk rating in areas of adequacy of cost estimating process, credibility of the cost estimate, and reserve posture

JPL Assessment (continued)

- After deliberation, JPL GPMC unanimously recommends approval to proceed to Phase B
  - Science is exciting, and will leave lasting legacy
  - Technical and cost risks are low to moderate, which is appropriate for a MIDEX cryogenic mission
  - There is some concern that NASA science review panel may recommend increase in minimum mission performance. A change to the minimum could impact the project's ability to meet it's commitments.
- The Jet Propulsion Laboratory is fully committed to supporting the WISE project during its future development phases

Wide-Field Infrared Survey Explorer (WISE)
Extended Phase A Technical, Management and Cost (TMC) Reassessment Summary

Carlos Liceaga
Earth and Space Science Support Office, LaRC, NASA

Dave Bearden, Bob Kellogg, Eric Mahr, Carl Rice and Lee Schumann
The Aerospace Corporation

Eileen Dukes, Shawn Hayes and Mark Jacobs
SAIC

August 25, 2004

Contents

- Technical Reassessment
- Management Reassessment
- Cost Reassessment
- Conclusions
- Backup Charts

- Silicon focal plane array (FPA) development risk reduced.
  - Detector lots meet necessary performance parameters.
  - Readout IC's (ROIC's) meet acceptable performance requirements but with readout artifacts.
  - Project plans for early Phase B study at DRS to determine if further optimization is warranted.
  - Decision within 1 month will not significantly affect schedule.
  - Use of current ROIC's is a viable option with slight performance impact.
  - ROIC and detector lots in hand will permit hybridizing necessary flight FPA's.
- Optical channel design risk reduced through
  - Reduction in primary mirror to 40 cm and other optical design work at SSG
  - Beam splitters and filter design studies with OCLI
- Risks in the performance and lifetime of the solid H_2 cryostat reduced through
  - Reduced size that brings design closer to WIRE
  - Large lifetime margin

- The concept study did not demonstrate a good understanding of the system level pointing budget errors.
- WISE performed a detailed extended Phase A image quality study.
- Peer review of image quality study, which included TMC representative, concluded
  - Requirements are now better defined and have been flowed down to the appropriate subsystems.
  - ADCS implementation has been greatly improved.
  - All error sources now appear to be accounted for and quantified.

Original major weakness:

- None of the key managers have flight project development management experience.
  - PI has not led a system-level flight project.
  - PM also does not have system-level flight project experience.
  - JPL Systems Engineer appeared to have limited relevant experience.
  - Ball PM did not show evidence of PM experience.

Feedback

- William Irace appears well-qualified for PM role.
- JPL Systems Engineer and Ball PM would benefit from additional institutional support in their new roles.

- This briefing provides a final update of the WISE TMC panel's cost findings and new ICE results for the revised design and implementation plan.

- The process used is similar to the TMC CSR evaluation with a few changes:
  - The SAIC independent estimate is from the Chicago group instead of the the Huntsville group that did the CSR estimate
  - A probabilistic cost-risk analysis has been added
    - The cost risk methodology is consistent with the state of the practice, however its inherent nature as a probabilistic model, dictates that it cannot be validated
    - Results were not considered in TMC risk rating
  - A Complexity-Based Risk Assessment from Aerospace has also been added

1) Review the WISE team's basis of estimate
   - Site visits to SDL and Ball

2) Monitor progress and new mission implementation plans
   - TMC provided feedback regarding mission redesign options, but did not provide independent cost estimates for the various options or direction for which option to select.

3) Update TMC independent cost estimates (ICE)
   - Based on March 2004 rebaseline
   - Results also include probabilistic analysis.

4) Reassess WISE cost risk
   - Consider progress and changes made in extended Phase A

- Instrument estimate reduced due to reduced aperture size and Extended Phase A technology maturation for the detectors
- Spacecraft estimate reductions from telecomm system simplifications and improved design maturity based on an additional year of Orbital Express development (OE is the design basis for the WISE s/c)
  - Reductions were partially offset by clean-up of errors in previous estimate and recent changes in the bus component breakout (from 4/15 to 5/7)
    - Some of the recent design changes were for claimed high-heritage items, which highlights concerns about heritage to systems currently in development
- Ground Data System costs reduced due to reduced data volume and data quality requirements
- Total reserves increased due to more conservative assessment of bus heritage (Aerospace) and different reserve estimate methodology (SAIC)

Extended Phase A Cost Estimate Comparison

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Notes: 1) Project costs from “All_Figures_4_thru_8_second_version_0425061-1.xls”, deflated using factors from “budget_cap_compliance.ppt”; 2) Numbers do not include the extended Phase A costs ($4,527K).

WISE Reserve Estimate Comparison

[illegible]	Project*	[illegible]	Range
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[illegible]	[illegible]	[illegible]	[illegible]

* Project reserves provided by FY only. Phase B/C/D vs. Phase E split estimated by TMC panel.

Extended Phase A Cost Estimate Changes Since CSR, pg 1 of 2

	Project Team Estimates				TMC Estimates			
	Ext PhA	CSR	$ change	% change	Ext PhA	CSR	$ change	% change
Development								
Payload	41,912	40,586	1,326	*3%*	46,179	51,314	-5,135	*-10%*
S/C	31,615	34,520	-2,905	*-8%*	42,728	43,592	-864	*-2%*
PM/SE/MA/GDS/Other	25,496	28,282	-2,786	*-10%*	27,444	34,028	-6,584	*-19%*
Reserves	24,342	21,227	3,115	*15%*	31,814	25,551	6,263	*25%*
DEV TOTAL	**123,366**	**124,615**	**-1,249**	***-1%***	**148,165**	**154,485**	**-6,320**	***-4%***
LV	**42,849**	**44,099**	**-1,250**	***-3%***	**42,849**	**44,099**	**-1,250**	***-3%***
OPS Total (w/ reserves)	**13,752**	**11,335**	**2,417**	***21%***	**9,602**	**10,725**	**-1,123**	***-10%***
TOTAL COST TO NASA	**179,966**	**180,049**	**-83**	***0%***	**200,615**	**209,309**	**-8,693**	***-4%***

NOTE:

- Costs for the extended Phase A are not included in any of these results; Impacts from extended Phase A activities have been taken into account in each TMC ICE, which resulted in a 5% decrease in the TMC ICE for Total Cost to NASA

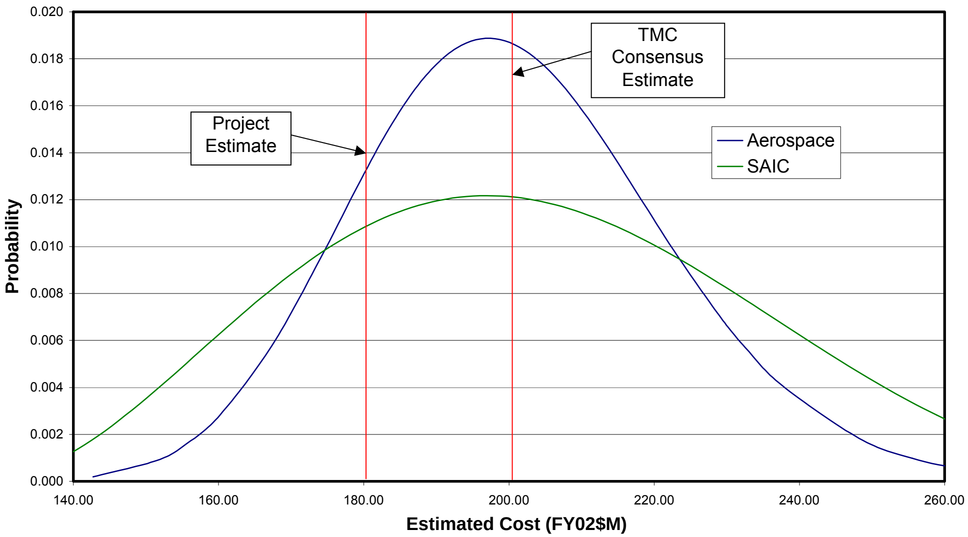
Extended Phase A Cost Estimate Changes Since CSR, pg 2 of 2

	Deltas between TMC and Project			
	Extended PhA		CSR	
	$ delta	% delta	$ delta	% delta
Development				
Payload	4,267	*10%*	10,728	*26%*
S/C	11,113	*35%*	9,072	*26%*
PM/SE/MA/GDS/Other	1,948	*8%*	5,746	*20%*
Reserves	7,472	*31%*	4,324	*20%*
DEV TOTAL	**24,799**	***20%***	**29,870**	***24%***
LV	**-**	***0%***	**(0)**	***0%***
OPS Total (w/ reserves)	**(4,150)**	***-30%***	**(610)**	***-5%***
TOTAL COST TO NASA	**20,649**	***11%***	**29,260**	***16%***

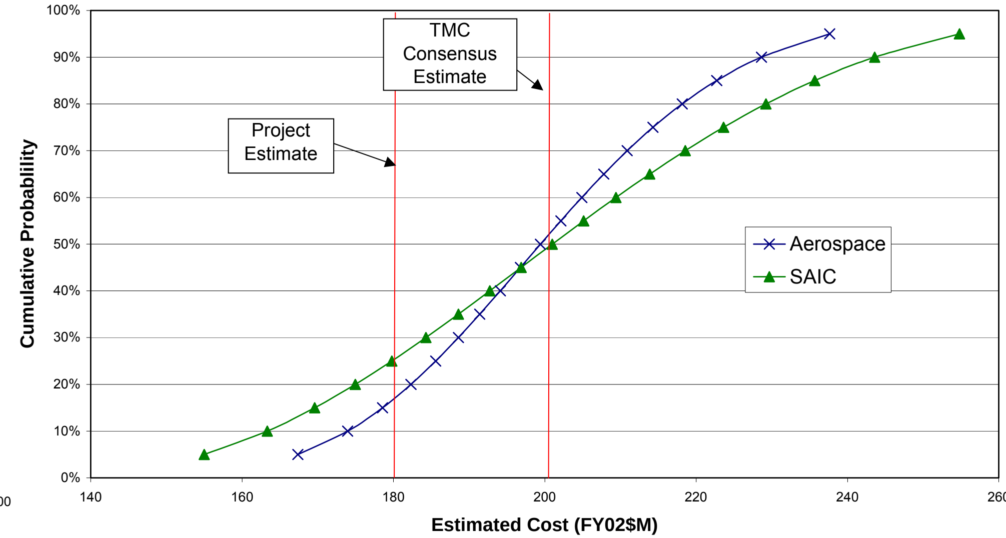
NOTE:

- Costs for the extended Phase A are not included in any of these results; Impacts from extended Phase A activities have been taken into account in each TMC ICE, which resulted in a 5% decrease in the TMC ICE for Total Cost to NASA

Probability Density Functions



Cumulative Probability Distributions

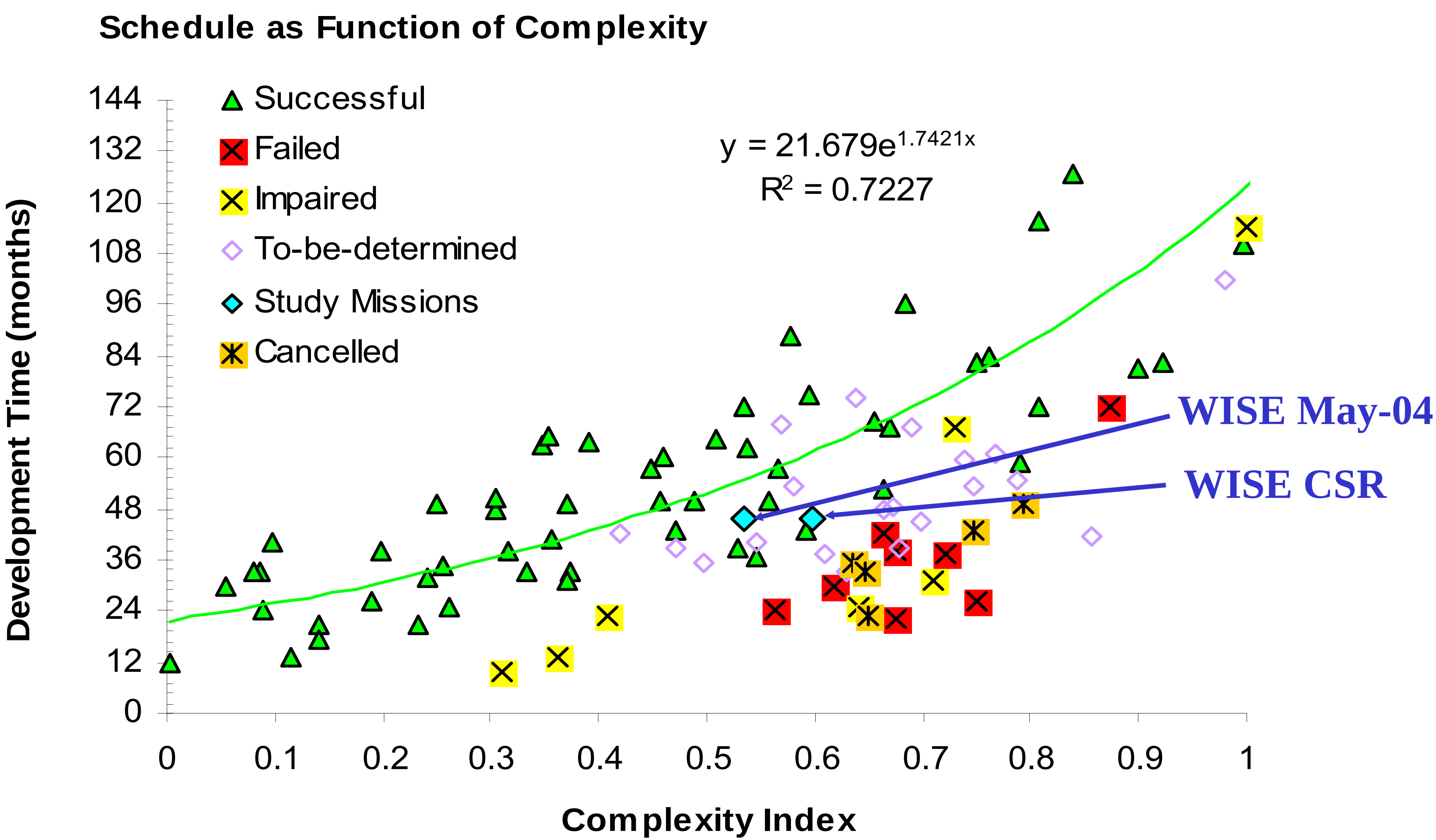


- The cost probability distributions capture an estimate of cost model error and uncertainty in key technical parameters.
- Many plausible risks are ignored.
  - Funding problems, LV availability, significant rescopes, "unusual" run of problems,…
- Cost risk methodology is consistent with the state of the practice, however its inherent nature as a probabilistic model, dictates that it cannot be validated.
- Results are best viewed as a tool to visualize magnitude of cost estimate uncertainty vs. difference between independent and project estimates, not the "probability of success" of the project.

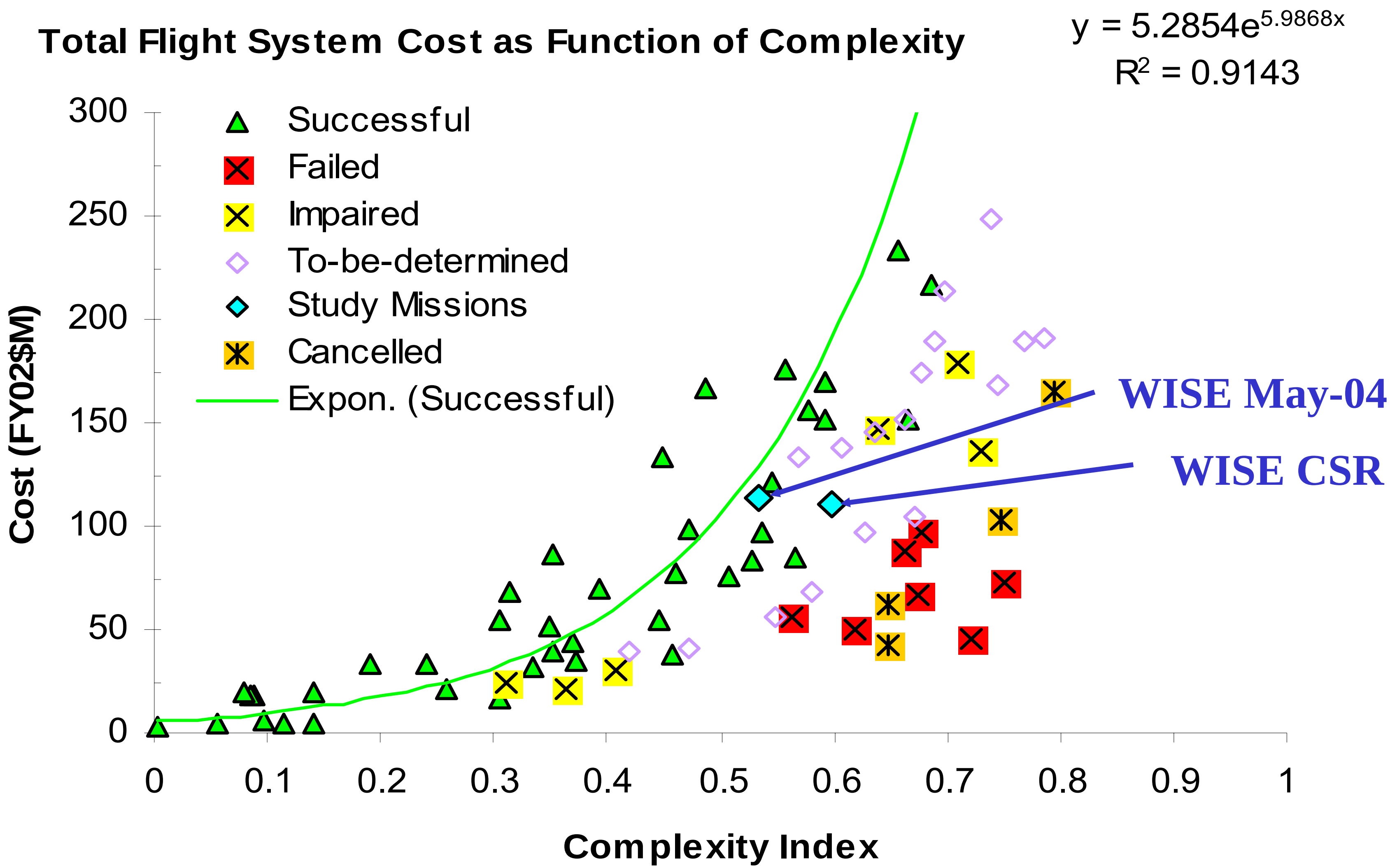
- Data assembled for most spacecraft launched during past decade (1989 to present).
  - Technical specifications, costs, development time, mass properties and operational status
  - Data fall into three general categories: NASA planetary; NASA earth-orbiting; and Other U.S. government systems.
- ***Complexity Index*** utilizes broad set of parameters to arrive at top-level representation of the system.
  - Based on performance, mass, power and technology choices
  - Used for purposes of comparison
  - Plotted against costs and development time
- Relationship between complexity and "failures" investigated.
  - Assess adequacy of cost and schedule resources
  - Implications for in-development systems

Extended Phase A Complexity Index Inputs

Factor	Unit	Min	Mean	Max	WISE (CSR)		WISE (5/04)	
Launch Date					**2007**		**2008**	
Total Development Cost	**(FY02$M)**	**1.4**	**225**	**2893**	**111**		**113**	
Development Time (actual)	**(mos)**	**10**	**50**	**228**	**46**		**46**	
Payload Mass	(kg)	0	233	6065	334	86%	289	84%
Payload Peak Power	(W)	0	153	592	153	58%	151	57%
Payload Data Rate (average)	(Kbps)	0	6278	95000	4650	81%	4634	80%
Number of Instruments		1	4	18	1	0%	1	0%
Aperture diameter	(cm)	13	121	600	50	55%	40	45%
Number of Channels	-	1	34	384	4	23%	4	23%
Data Volume	(MB/day)	0	8328	77800	77800	91%	50600	89%
Foreign Partnership		None	GS, LV, SC Bus	PL, mult PL	0	0%	0	0%
Mission Design Life	(mos)	0	38	197	13	21%	13	21%
Launch Mass Margin	(%)	4%	24%	60%	26%	37%	46%	11%
Satellite Launch Mass (Wet)	(kg)	12	941	18189	532	57%	459	51%
Satellite Mass (Dry)	(kg)	6	825	16329	532	63%	459	54%
Spacecraft Bus Dry Mass	(kg)	26	574	10264	198	43%	170	38%
Spacecraft Heritage	(%)	0%	45%	100%	80%	31%	80%	31%
Level of Redundancy	(%)	0%	35%	100%	5%	25%	5%	25%
Orbit Regime		STS/ISS, GEO	LEO/MEO, H-LEO/Dip, NE	Interplan (au)	1	11%	1	11%
EOL Power	(W)	3	585	4860	702	68%	702	68%
Solar Array Area	(m^2)	0	6	100	2.6	33%	2.6	33%
Solar Cell Type/Power Source		Si	GaAs, GaAs-mult	GaAs-conc, RTG	GaAs-mult	75%	GaAs-mult	75%
Battery Type		Lead-acid	NiCd, SNiCd	NiH2, Li-Ion	Li-Ion	100%	Li-Ion	100%
Battery Capacity	(A-hr)	1	33	360	36	71%	36	71%
# Articulated Structures		0	1	13	2	80%	1	58%
# Deployed Structures		0	2	20	1	31%	1	31%
Solar Array Configuration		body-fixed	deployed, single-axis	articulated	D	33%	D	33%
Structures Material		Aluminum	Al w/Comp-face, Exotic	Composite	comp face	33%	comp face	33%
ADCS Type		None/Magnetic	GG, Spin, 3-axis, Hi-spin	3-axis (ST), Dual	3-axis-ST	80%	3-axis-ST	80%
Pointing Accuracy	(deg)	0	2	35	0.062	70%	0.04	75%
Pointing Knowledge	(deg)	0	1	20	0.0500	51%	0.042	53%
Platform Agility (slew rate)	(deg/sec)	0	1	5	0.06	48%	0.06	48%
Number of Thrusters+Tanks	(#)	0	6	26	0	0%	0	0%
Propulsion Type		None, Cold-Gas	Mono, Biprop-(blow,pres)	OB+US, Ion	none	0%	none	0%
Total Impulse (delta-V)	(m/sec)	0	327	5845	0	0%	0	0%
Downlink Comm Band		UHF/VHF/SHF	S, L	X, Ka/Ku	Ku	100%	Ku	100%
Max Downlink Data Rate	(kbps)	1	9698	300000	300000	98%	120000	93%
Max Uplink Data Rate	(kbps)	0	40	2000	2.0	27%	2.0	27%
Central Processor Power	(Mips)	0	61	1600	119	87%	119	87%
Flight Software Reuse	(%)	0%	38%	90%	80%	26%	80%	26%
Data Storage Capacity	(Mbytes)	0	3984	136000	85900.0	98%	85900.0	98%
Thermal Type		passive	heaters, semi-active	active, cryo	cryo	100%	cryo	100%
Multi-Element System?		single-sc	CL, multiple-sc (aerobrake, rend)	entry/landed/dock	cl	33%	cl	33%
Complexity Index		**4%**	**40%**	**77%**		**51%**		**49%**
Normalized Complexity Index		**0%**	**50%**	**100%**		**64%**		**61%**
Time-Dependent Complexity Index						**60%**		**53%**


Schedule as Function of Complexity
Successful
Failed
Impaired
To-be-determined
Study Missions
Cancelled
y = 21.679e^1.7421x
R² = 0.7227
WISE May-04
WISE CSR
Development Time (months)
Complexity Index
144
132
120
108
96
84
72
60
48
36
24
12
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Extended Phase A
Flight System Cost vs. Complexity



- The project has reduced risk by maturing technology for the detector electronics, reducing the size of the telescope and cryostat, and simplifying the spacecraft bus.
  - These changes reduced TMC spacecraft and instrument estimates.
- TMC ICE results for Total Cost to NASA are still higher than project estimates, but much closer than at the beginning of the extended Phase A.
  - TMC results are higher for development (Phases A-D) and lower for operations (Phase E).
- Recommend use of dedicated JPL person to closely track project cost performance (e.g., using EVM).
  - JPL should take advantage of cost tracking systems contractors already have in place (e.g., Ball has EVM).
  - This is consistent with recent JPL practices for Deep Impact and Dawn, where a JPL Business Manager is dedicated full-time to a single mission.

Conclusions - Cost Risk Rating

Low Risk			Medium Risk			High Risk		
9	8	7	6	5	4	3	2	1

- Rating: 5.8 (used to be 4)
- Rationale: The WISE team has made significant improvements to the cost credibility of the WISE project during the extended Phase A. The smaller instrument should reduce cost risk for both the instrument and the spacecraft bus. Reductions in data volume, clarification of mission-unique launch costs, and numerous smaller changes have also reduced costs for the project. The technical progress made has reduced technical risk, which is reflected in the lower cost estimates. The team has also increased their cost reserves to an acceptable level and clarified their descope strategy. TMC concerns include cost risks associated with the complex cryogenic payload and reliance of the spacecraft bus design on heritage from a project currently in development. Also, the TMC independent estimates remain above the project estimates (by $15-27M) but are much closer than before the extended Phase A. For these reasons the cost could not be rated low risk, but it is on the low end of medium.

Conclusions - TMC Risk Rating

Low Risk			Medium Risk			High Risk		
9	8	7	6	5	4	3	2	1

- Rating: 6.7 (used to be 4)

- Rationale: The WISE team has addressed all major weaknesses from the concept study review. They have demonstrated a flight quality focal plane assembly, developed a credible pointing budget, strengthened the management team, and improved the cost credibility. They are now in a much better position to start a Phase B than they were a year ago. The only remaining concerns are those associated with any cryogenic instrument development and the cost risks associated with the spacecraft and payload development.

Backup Charts Contents

1) Technical Reassessment Details

2) Additional Extended Phase A Cost Estimate Data

3) Complexity-Based Risk Assessment (CoBRA) Backup Material

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

1) Technical Reassessment Details

- Silicon focal plane array development
  - Fallback plans described in the CSR introduced performance shortfalls and potential schedule impact.
  - This was designated a major weakness in the TMC evaluation.
- Optical channel design
  - This was designated a minor weakness by the TMC but, in addition, is a common source of project difficulties for space projects using advanced optical designs.
  - Specific areas called out were
    - Optical throughput and stray light
    - Dichroics and filters performance and manufacturability
- Performance and lifetime of the solid hydrogen cryostat
  - Lowered lifetime and performance have been common characteristics of solid hydrogen cryostats flown to date.

- WISE did not demonstrate a good understanding of the system level pointing budget errors, e.g., uncompensated orbital rate variation.
- The strategy to respond to a scan mirror rate mismatch with the orbital rate is not yet defined and there is little margin to accommodate such errors.
- The 0.6 arcsec over 6.6 sec requirement is challenging for the CT-633.
- Variation in attitude knowledge combined with large disturbance torques raises doubts, and may require costly upgrades for a better star tracker or improved gyros, or have impacts to science.

What the Project Has Done

- WISE performed a detailed extended Phase A image quality study.
  - Study led by Ball Aerospace ADCS engineer.
  - Study included science, SDL, optics provider.
- *WISE Image Quality Report* published April 2004.
- WISE image quality error budget peer review held April 2, 2004.
  - Board members included JPL (Chair) experts, TMC representative, and GSFC representative.
  - Final board report was favorable.

- Excellent team work in working system pointing budget.
  - Appears that all affected teams participated.
  - Image quality allocations are being flowed down to the appropriate subsystems (optics, ADCS, etc.) as requirements.

- Adopted noise pixel methodology to quantify and combine errors.
  - Noise pixels are a measure of the size of the point-spread-function of a telescope and can be thought of as an equivalent number of pixels contributing to random noise.
  - Methodology endorsed by the PI.
  - All error sources now appear to be accounted for and quantified.

Assessment of Results (cont.)

- Design and operational changes have been made during Phase A, some as a result of the study.
  - Fixed HGA eliminates stepper motor jitter.
  - Reorient (“catch-up”) twice per orbit vs. once in CSR
  - Scan mirror has 16 discrete rates which will be picked by in-flight calibration.
  - Reaction wheel orientation established as pyramid with momentum bias avoids low speeds and zero crossings.
    - Fine-balanced wheels specified
  - Discrete momentum dumping events reduces continuous disturbance.
  - Attitude determination using star tracker only (“gyro-less”) improves performance.
    - CT-633 star tracker has higher performance than “off-the-shelf” with increased characterization.

Conclusions

- WISE project has greatly improved their image quality position.
  - Better defined requirements
  - Improvements in ADCS implementation

- Some pointing budget allocations still seem optimistic but adequate margin is distributed for each element and at system level.

- The concept study weakness has been adequately addressed.

2) Additional Extended Phase A Cost Estimate Data

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Extended Phase A
Cost Estimate Comparison

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Notes: 1) Project costs from "All_Figures_4_thru_8_second_version_0425061-1.xls"; 2) Numbers do not include the extended Phase A costs ($4,790K).

Cost Estimate Profiles
Phase B/C/D/E Costs Without Launch Vehicle

[illegible]	2005	2006	2007	2008	2009	2010	Total
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[illegible]	2005	2006	2007	2008	2009	2010	Total
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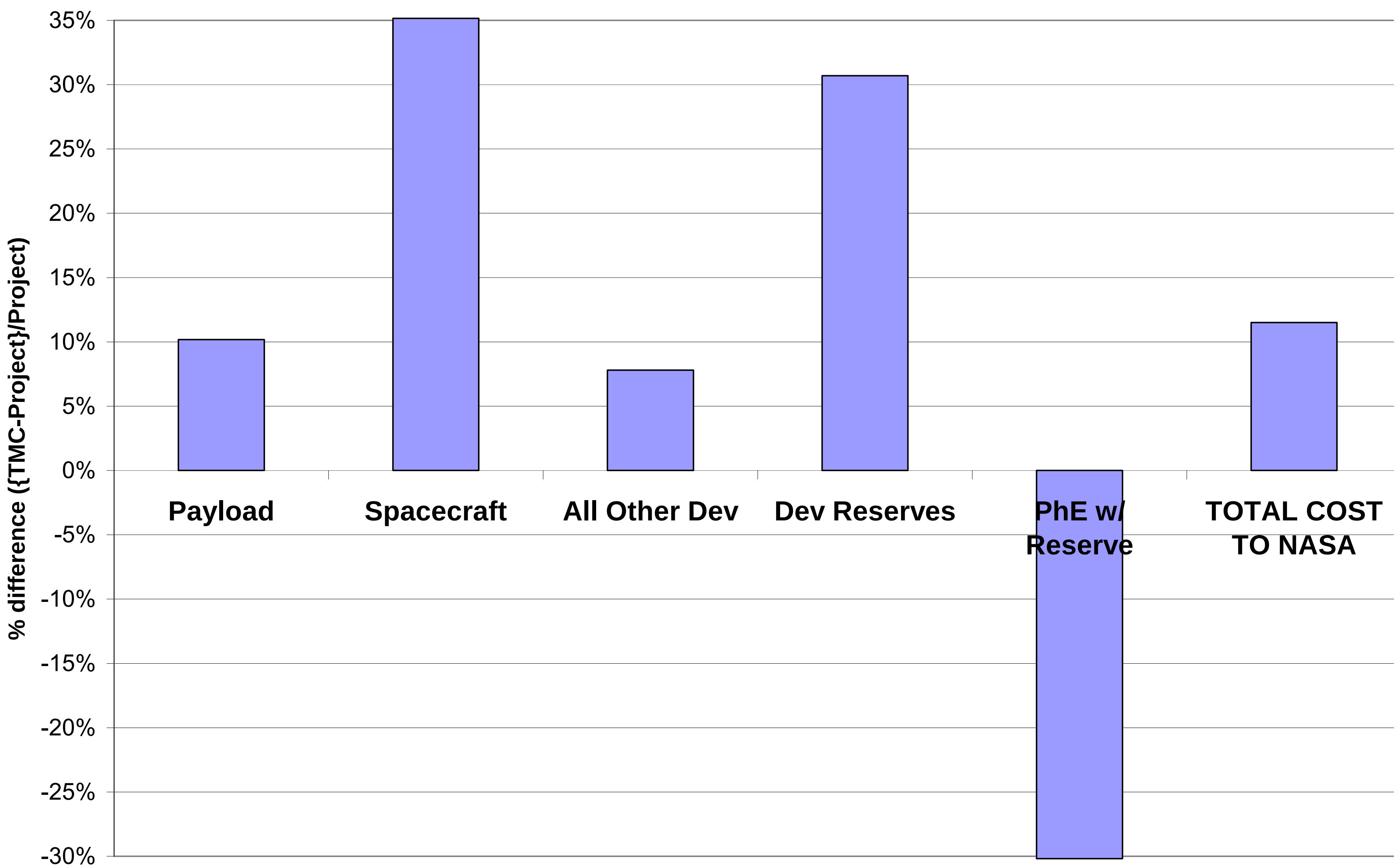
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Comparison of TMC Consensus ICE and Project Extended Phase A Estimates



3) Complexity-Based Risk Assessment (CoBRA) Background Material

- Complexity drivers include . . .
  - Demonstrable subsystem technical parameters, e.g., mass, power, performance, technology choices, etc.
  - Programmatic factors, e.g., heritage, level of redundancy, foreign partnership, etc.
- Utilize up to 40 parameters consisting of . . .
  - Continuous (e.g. mass, power) that represent a range of values bounded by a minimum and maximum; and
  - Discrete such as propulsion type (none, cold gas, monoprop, biprop, or ion engine) that represent a finite number of choices
- Calculation Process:
  - Calculate individual (single-parameter) indices
  - Average individual indices to derive mean index
  - Normalize mean index between 0 and 100%
- Plot complexity versus cost and development time

- Total flight system cost
  - Includes formulation and implementation (Phase B/C/D)
    - Spacecraft bus
    - Payload instruments
    - Program management/systems engineering (PM/SE)
    - Integration, assembly and test (IA&T)
    - Ground support equipment (GSE)
    - Launch support/early orbit operations (LOOS)
  - Launch, ground systems and operations costs excluded

- Development time
  - Includes formulation and implementation (Phase B/C/D)
  - Time from contract start (SRR or ATP, earliest) to “launch ready” (ship-date or 1 month prior to launch)

CoBRA Ground Rules

- Over 120 recent (>1989) U.S.-built missions included
  - Large DoD and NASA missions
  - NASA Small-to-Medium (Discovery Class) missions
  - NASA Earth-orbiting missions
  - DoD/Other Earth-orbiting missions
- Missions yet to complete significant portion of mission or awaiting launch categorized as “to-be-determined”.
- Missions that rely heavily on unknown international contributions not considered.
- Launch-vehicle-related delays (where identifiable) excluded.
- Launch-related failures included in complexity calculation, but excluded from summary statistics.
- Programs cancelled due to budget overruns or schedule slips included as programmatic “failures”.

NASA Near-Earth/Planetary

ACE	Cassini
Clementine	CONTOUR
Deep Impact	DS1
	GENESIS
Galileo	Lunar Prospector
Magellan	Mars Observer
Mars Odyssey	Mars Pathfinder
MAP	MCO
MER	MGS
MPL	MRO
NEAR	New Horizons
SIRTF	Stardust
SOHO	STEREO
TRIANA	Ulysses
Wind	

NASA Earth Orbiting

ACRIMSat	Aquarius
AXAF	Calipso
CGRO	CHIPSat
Clark	Cloudsat
CORIOLOS	EO-1
EO-3	EOS-Aqua
FAST	FAME
FUSE	GALEX
GP-B	GRACE
HESSI	HETE
HETE-2	HST
ICESat	IMAGE
Jason-1	Lewis
METEOR	MICROLAB
OCO	Polar
QuickSCAT	QuikTOMS
SAMPEX	Seastar
SWAS	TDRSS
TIMED	TOMS-EP
TOPEX/Poseiden	TRACE
TRMM	ST-5
UARS	VCL
WIRE	XTE

DoD/Other Earth Orbiting

ALEXIS	APEX	DARPASAT
DSP	FORTE	GEOLite
GFO	GPS	Iridium
LOSAT-X	MACSAT	MICROSAT
MightySat I&II	Milstar	MSTI 1-3
ORBCOMM	PEGSAT	POGS/SSR
RADCAL	REX I&II	SCE
STEP 0-4	STEX	TEX
TSX-5	UFO	

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